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AN INVESTIGATION TO DETERMINE A SATISFACTORY STANDARD FOR BERIBERI-PREVENTING RICES *

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TWO PLATES AND EIGHT TEXT FIGURES

I. THE METHOD EMPLOYED

Although medical authorities still differ with regard to a number of details concerning the etiology of beriberi, there is a very general consensus of opinion to the effect that beriberi is a deficiency disease, produced whenever, in the absence of an adequate mixed diet, highly milled rice is used as the main food staple, and that the disease can be prevented by the substitution of a sufficiently undermilled rice. The most striking illustration of this fact with which we are familiar is the case of the Philippine Scouts. For a number of years (1902–1909), while they were supplied with the best grade of highly milled rice, beriberi was the most important cause of admission to sick report for these native troops, the incidence often reaching as high as 10 per cent of the entire number (5,000). In 1910 the substi-

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tution of undermilled rice was made. Beriberi at once declined as a cause of admission and at the end of a year, when the substitution had been made universally effective, beriberi was completely eradicated. Since that time undermilled rice only has been furnished, and during all these years beriberi has completely ceased to appear among these troops, although they were living in the midst of a population where beriberi is very common. Similar results have been obtained in a number of civil institutions in the Philippines as well as in other countries.

Such experiences led several sanitary authorities to recommend legislation by the various countries most concerned, which would diminish the production or importation of highly milled rice; but it was promptly realized that no such law could be administered without a satisfactory legal standard for beriberi-preventing rices.

Fraser and Stanton originally recommended a standard of 0.4 per cent phosphorus pentoxide, and for a long time this standard was supposed to be satisfactory. Later observations, by Schüffner and Kuenen,(1) and McCarrison and Norris(2) and others have shown clearly that a number of rices containing 0.4 per cent or more may produce beriberi. Schüffner and Kuenen(1) stated that rice should contain at least 0.5 per cent phosphorus pentoxide. It is unnecessary to dwell on this point, for all will agree that up to the present time no satisfactory standard has been established.

The resolution passed by the Far Eastern Association of Tropical Medicine in its 1925 meeting included statements to the effect that nothing has occurred to controvert the disappearance of beriberi when an adequate diet is used; that the governments concerned should encourage research toward developing a practical test to distinguish between rices that may cause beriberi and rices that may prevent beriberi when used as a staple of diet; and that facts be collected which may be used in classifying rice in its different stages in the process of milling.

Beriberi cannot be eradicated without legislation in the countries in which it is endemic, and legislation waits on the determination of a satisfactory standard for beriberi-preventing rices. Therefore, when one of us was assigned to the United States Army Medical Department Research Board at Manila, it appeared that this was the most important problem connected with beriberi awaiting solution. Work was commenced in October, 1925, and was continued without interruption until October, 1927.

Plan of the work.—It was determined to procure series of two hundred samples of rice, grown in different localities and of all degrees of milling. These rices were to be inspected to determine the percentage of the external layers of the grain still adhering to them, and were to be submitted to chemical analysis. At the same time they were to be fed to pigeons to determine their actual beriberi-producing potentialities. The chemical analyses and the feeding experiments were to be carried on independently, and the results so obtained subsequently combined. The actual details of this simple plan are given fully, in order that there may be no question as to how the results were obtained.

1. Procurement of rice samples.—Twenty samples were purchased in the open market. These samples were all machine-milled, but came from widely separated localities (three were from China), and the degree of milling was by no means uniform.

Twelve rices were secured from the Quartermaster of the United States Army. Seven were samples of undermilled rice furnished the Philippine Scouts and five were samples of choice, highly milled rice. Each sample was from a different purchase by the Quartermaster from wholesale dealers.

Samples 10 to 15, inclusive, were obtained as follows: Two different varieties of unhusked rice (palay) were taken to a primitive mill in which the milling of rice was carried on by water power. As the water wheel revolved it lifted heavy pestles which were later released and fell into stone mortars. Both of these samples of rice were submitted to this milling action for varying periods of time. The sample first removed (No. 1) was undermilled, that removed next (No. 2) was more completely milled, and the third and last (No. 3) was highly milled white rice. By consulting the tables it will be seen that both samples of rice, when undermilled, prevented the appearance of polyneuritis when fed to pigeons, and that polyneuritis occurred with both samples when highly milled.

Ten samples of rice (palay) were sent to us from Java, through the courtesy of General H. M. Neeb and Dr. P. J. S. Cramer, director of the Experiment Station, Department of Agriculture, Java. These samples were hand-pounded in Manila, thus receiving different degrees of polishing.

The remaining one hundred fifty-two samples were procured for us by Dr. Stanton Youngberg, director of the Bureau of

Agriculture of the Philippines. These samples of many different varieties of rice were procured from various islands and provinces of the Philippines, and were all hand-pounded, so that no two rices were precisely similar in degree of milling. We wish here to express our obligation to Doctor Youngberg. Without his cordial and continued coöperation, it would have been impossible to obtain such a large series of different rices.

Ten kilograms of each sample of rice were purchased. The rice was kept in tightly covered tin cans in a dry storeroom, and each can labeled with the serial number of the rice. As experience promptly showed that weevils, moths, and other insects developed in rice so kept, a vial of chloroform with a loose stopper was buried in each sample. The escaping vapor promptly killed all insects, and the rices kept in this manner remained in good condition during the one hundred days that the experiment lasted.

2. Inspection for pericarp.—One hundred grains of rice, taken at random, were stained with Gram's iodine solution for one minute, after which the iodine was rinsed off with water. Each grain was then examined, and the amount of pericarp remaining was expressed as a percentage, the whole pericarp with the rice embryo intact representing 100 per cent. This method appears very rough and inaccurate, yet long experience in selecting undermilled rices for the Philippine Scouts had demonstrated the fact that it is possible in this way to pick out invariably a grade of rice that will prevent beriberi. The results of this inspection are included in Table 1.

3. Chemical analyses.—The antineuritic vitamin is undoubtedly chiefly contained in the embryo and the aleurone layer of the rice grain. The outer layer, the pericarp, contains a high percentage of mineral matter, and if most of the pericarp is retained the embryo is often also present. The majority of the fat of the grain occurs in the aleurone layer. For these reasons, the chemical estimation of mineral salts (ash) or fat might be as good an index as phosphorus pentoxide, which was chosen only because the phosphorus of the grain is also chiefly contained in these external layers. None of these substances is chemically related to the antineuritic vitamin, which contains no phosphorus, fat, or mineral salts. This vitamin, however, is a nitrogenous compound and, in the absence of any direct chemical test or satisfactory color reaction for its precise quantitative

estimation, there was a possibility that amido-nitrogen content might prove to be a good chemical index.[1] Total nitrogen is valueless because the protein of rices varies considerably, irrespective of the vitamin content. The methods used (Feliciano) were as follows:

(*1*) *Moisture.*—Determined by drying a known weight of sample (5 grams) in an electric oven at 100 to 105° C. until a constant weight was obtained. The loss of weight represents the moisture present.

(*2*) *Ash.*—Ash was determined by properly incinerating the dried sample from the moisture determination. The weight of the white or gray residue, free from carbon, represents the ash content.

(*3*) *Fat.*—Fats were determined by extracting a weighed sample of dried, finely powdered rice with pure ether in a Soxhlet apparatus for forty-eight hours. The extract was freed from ether and moisture, and weighed. This result was checked by drying the extracted rice and finding the loss in weight.

(*4*) *Phosphorus pentoxide.*—One gram of the sample is carbonized in a porcelain dish. Add 0.2 to 0.4 gram magnesium nitrate. Ash until white. Place the dish containing the ash in a beaker of 400 cubic centimeters and add a sufficient quantity of concentrated nitric acid, immediately followed by distilled water. Heat until solution is obtained. Neutralize the acid with ammonia, then add two or three drops of concentrated nitric acid. Add 25 cubic centimeters of the molybdic acid solution. Stir to induce precipitation, and let stand in a warm place at about 40° C. overnight. Filter through purified asbestos, wash thoroughly with cold water until free from acid, then transfer back to original beaker. Add 50 cubic centimeters distilled water and 40 cubic centimeters N/10 sodium hydroxide. Heat until precipitate is completely dissolved. Titrate back excess sodium hydroxide with N/10 sulphuric acid using phenolphthalein as indicator. Calculate as phosphorus pentoxide.[2]

(*5*) *Nitrogen.*—Nitrogen was determined by Gunning's modification of Kjeldahl's method.

[1] This was originally suggested by Chamberlain, Vedder, and Williams in, A third contribution to the etiology of beriberi, Philip. Journ. Sci. § B 7 (1912) 39.

[2] See Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists, page 2.

(6) *Amido-nitrogen.*—Albuminoid nitrogen is determined, and subtracted from the total nitrogen to obtain the amido-nitrogen.

(7) *Albuminoid nitrogen.*—Place 0.7 gram of the sample in a beaker. Add 100 cubic centimeters water, and heat in a steam bath for ten minutes; add a quantity of cupric hydroxide reagent containing about 0.5 gram of the hydroxide; stir and filter when cold; wash with cold water, and without removing precipitate from filter determine the nitrogen by Gunning's modification of the Kjeldahl method. The filter paper used must be free of nitrogen.[3]

All results were calculated on the original weight of the rice rather than on the dry weight, because this is the method in general use in determining the phosphorus pentoxide content of rices submitted for routine analysis, since rice is not sold or consumed by dry weight. However, the percentages by dry weight were calculated for a considerable number of the rices in the hope that this more accurate method would reduce the number of rices producing irregular results. It was found that there was no significant difference in the ultimate results, whether calculations were made on original weight or on dry weight.

4 *Feeding experiments.*—Pigeons were selected for feeding, because they are even more susceptible to polyneuritis than fowls and are readily handled. Four pigeons were fed upon each sample of rice, allowing them all that they would eat. A jar of water was in each cage, but no other food was given or was obtainable by the birds. The birds were fed and observed daily by one of us (Vedder), and the date on which each bird first developed symptoms of polyneuritis was observed and entered in a notebook. The bird was watched until it became obviously paralyzed, often with retraction of the neck. When thus on the point of death, the bird was treated by administering small amounts of rice polishings (tikitiki) or an extract of the same. Prompt recovery after this treatment was almost invariable and confirmed the original diagnosis of polyneuritis (Plate 1). In cases of death without obvious symptoms of polyneuritis, a post-mortem examination was made to determine the cause of death, and the sciatic nerves were removed and stained by the Marchi method to determine the existence of degeneration. In any case in which the results of this feeding experiment could be con-

[3] Op. cit., Chapter IX, pars. 9 and 10.

sidered doubtful, because of loss of birds from intercurrent disease or for other reasons, the experiment on that rice was repeated with a new group of birds. Therefore, nearly nine hundred birds were used.

The pigeons under experiment were confined in groups of four, in a series of fifty-six wire cages 36 by 36 by 30 inches, placed upon a concrete foundation, and covered by a galvanized-iron roof. Each cage was numbered and provided with a bamboo roost and a similarly numbered wooden box to hold the rice. The cages (shown in Plate 2) were ideal for the experiment and were specially constructed by the Bureau of Science for this purpose. We desire here to express our obligation to Dr. William H. Brown, the director of the bureau, for providing us with these cages, and for facilitating the work in every possible way.

In estimating the beriberi-producing potentiality of a rice there are two factors to be considered; namely, the number of individuals that develop the disease, and the rapidity of development of the disease. An attempt has been made to express both of these factors in a single figure called the beriberi-producing factor. The number of birds that developed beriberi was expressed as the percentage of the total number used in the experiment, and this percentage was divided by the average number of days elapsing from the time the rice was first fed until the first symptoms of polyneuritis appeared. Thus, the higher the percentage of the birds that developed beriberi, and the shorter the depletion period, the greater does this beriberi-producing factor become.

Pigeons may occasionally develop polyneuritis as early as fifteen days on a very deficient rice. If none of the four birds developed polyneuritis after one hundred days of feeding, it was assumed that the rice afforded sufficient protection, and the experiment was discontinued. In this connection it may be emphasized that, as pigeons are far more susceptible to polyneuritis than is the human race to beriberi, it may reasonably be claimed that any rice that protects pigeons from polyneuritis for one hundred days will prevent the appearance of beriberi in man, even when used as an exclusive diet, which is seldom the case.

The results of this work, including the chemical analyses of each rice, with the effect of feeding to fowls, are presented in Table 1. The figures for each chemical ingredient were also

TABLE 1.—*Chemical analyses of various rices and results of feeding same to pigeons.*

No.	Name.	Locality.	Pericarp remaining.	Chemical analysis.							Result of feeding.	
				Moisture.	Fat.	Phosphorus pentoxide.	Ash.	Total.	Nitrogen.	Amido-nitrogen.	Beriberi.	Beriberi factor.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	
1	B.	Nueva Ecija	10		0.72	0.39	0.61	1.72	1.27	0.18	50	0.96
2	No. 2 red	Pampanga	60		1.37	0.59	0.91	2.87	1.02	0.38	0	0
3	H	Nueva Ecija	0		0.70	0.31	0.70	1.71	1.12	0	50	1.10
4	B	Tarlac	8		0.77	0.42	0.85	2.04	1.03	0	100	1.92
5	A	Pangasinan	10		0.71	0.45	0.71	1.87	1.16	0	75	1.78
6	No. 1 red	Pampanga	15		0.71	0.47	0.89	2.07	1.10	0	75	1.50
7	Magalang red	do	5		0.82	0.40	0.60	1.82	1.05	0.55	75	1.59
8	Scout rice	Pangasinan	95		1.84	0.73	1.13	3.70	1.14	0.43	0	0
9	Choice rice	Pampanga	0		0.30	0.25	0.35	0.90	1.23	0.05	100	4.00
10	Apostol No. 1	Laguna	90		1.64	0.66	1.19	3.49	1.05	0.02	0	0
11	Apostol No. 2	do	24		1.03	0.53	1.04	2.60	1.09	0.01	25	0.03
12	Apostol No. 3	do	10		0.50	0.39	0.64	1.53	1.03	0.12	100	3.03
13	Mangasa No. 1	do	95		1.74	0.69	1.27	3.70	1.17	0.14	0	0
14	Mangasa No. 2	do	80		1.18	0.58	1.05	2.81	1.16	0.12	0	0
15	Mangasa No. 3	do	5		0.49	0.36	0.72	1.57	1.09	0.04	100	3.47
16	Choice rice	Pampanga	0		0.54	0.33	0.50	1.37	1.00	0.16	100	3.70
17	do	do	0		0.54	0.39	0.50	1.43	1.13	0.04	100	1.75
18	Scout rice	do	95		1.35	0.56	0.88	2.79	1.14	0	0	0
19	AA	Tarlac	5		0.81	0.44	0.60	1.85	1.12	0.05	100	2.56
20	AX	do	5		0.94	0.39	0.63	1.96	1.03	0	100	2.56
21	No. 2 red	do	90		1.76	0.55	1.08	3.39	1.14	0.12	0	0
22	Inantipolo	Rizal	85		1.07	0.55	0.82	2.44	0.98	0	0	0
23	Mamabunac	do	10		0.94	0.47	0.76	2.17	0.93	0.01	75	2.56
24	Binankero	do	10		1.04	0.46	0.75	2.25	1.05	0.02	100	1.85
25	Scout rice	do	95		2.69	0.78	1.20	4.67	1.23	0.05	0	0

26	Choice rice	Pampanga	8		0.57	0.43	0.65	1.65	1.04	0	100	2.27
27	Ymonga	Laguna	85	10.54	1.34	0.64	1.04	3.02	1.23	0	0	0
28	Lawlaw	do	95	10.98	1.95	0.97	1.36	4.28	1.59	0.05	0	0
29	Mangasa	do	95	10.37	1.84	0.49	0.81	3.14	1.26	0.05	0	0
30	Kiniristina	do	80	10.85	1.20	0.73	1.17	3.10	1.60	0.05	0	0
31	Dinomero	do	98	11.13	2.03	0.86	1.46	4.35	1.18	0.06	0	0
32	Kinasasay	do	83	10.26	3.03	0.73	1.22	3.98	1.20	0.06	0	0
33	Sineñora	do	88	10.30	1.81	0.67	1.03	3.51	1.02	0.06	0	0
34	Saigon	Nueva Ecija	80	10.37	1.60	0.40	0.61	2.61	1.12	0	0	0
35	Minalbon	do	77	10.89	1.16	0.52	0.74	2.42	1.26	0.05	0	0
36	Guinobierno	do	68	10.79	1.31	0.71	0.85	2.87			0	0
37	Penas	Pangasinan	90	9.93	1.59	0.77	1.09	3.45			0	0
38	Ubanan	do	78	10.13	1.81	0.75	1.02	3.58			0	0
39	Minalabon	do	80	9.71	1.43	0.70	1.01	3.13			0	0
40	Mimis	do	88	9.31	1.49	0.76	1.17	3.42			0	0
41	Imachupal	do	85	9.69	1.57	0.63	1.02	3.22			0	0
42	Scout rice, QMC	Rizal	98	10.76	1.99	0.73	1.05	3.77			0	0
43	Choice rice, QMC	Pampanga	5	11.16	0.66	0.49	0.65	1.80			75	1.00
44	Tiniaong	Laguna	96	13.22	2.05	0.81	1.35	4.21			0	0
45	Mangasa	do	94	11.80	2.19	0.82	1.32	4.33			0	0
46	Kalibo	do	95	11.20	2.43	0.85	1.38	4.66			0	0
47	Binangbang	do	97	13.23	2.06	0.79	1.40	4.25			0	0
48	Binikol	do	90	12.34	1.84	0.79	1.28	3.91			0	0
49	Magsalit	do	96	11.48	2.51	0.82	1.36	4.69			0	0
50	Sinadyaya	do	92	12.05	1.90	0.84	1.34	4.08			0	0
51	Makan	do	98	11.94	2.36	0.74	1.37	4.47			0	0
52	Vinagat	do	98	12.18	2.13	0.84	1.38	4.35			0	0
53	Quinanda	do	90	13.01	1.25	0.82	1.35	3.41			0	0
54	Sipot	Pangasinan	75	11.35	1.07	0.64	1.04	2.75			0	0
55	Bulastog	do	87	11.80	1.22	0.63	0.94	2.79			0	0
56	Kalibo	do	82	11.55	1.17	0.64	1.10	2.91			0	0
57	Madaling aras	do	87	12.52	1.15	0.63	1.11	2.89			0	0
58	Scout rice, QMC	Pampanga	97	10.79	1.78	0.72	1.10	3.60			0	0
59	Macan lamio	Nueva Ecija	10	11.80	0.22	0.52	0.89	1.63			50	1.63
60	Guinubierno	do	15	12.02	0.92	0.33	0.64	1.89			75	1.53

TABLE 1.—*Chemical analyses of various rices and results of feeding same to pigeons*—Continued.

No.	Name.	Locality.	Pericarp remaining.	Chemical analysis.							Result of feeding.	
				Moisture.	Fat.	Phosphorus pentoxide.	Ash.	Total.	Nitrogen.	Amidonitrogen.	Beriberi.	Beriberi factor.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	
61	Dinagupan	Nueva Ecija	15	12.48	0.78	0.48	0.64	1.90			100	1.85
62	Macan cumpul	do	50	11.74	1.37	0.60	0.96	2.93			0	0
63	Mimis	do	15	12.69	0.67	0.59	0.83	2.09			50	1.04
64	Minanteca	do	25	11.91	0.77	0.61	0.87	2.25			75	1.12
65	Macan neining	do	16	11.54	0.91	0.52	0.86	2.29			75	0.91
66	Minalabon	do	10	12.37	0.91	0.47	0.69	2.07			75	0.73
67	Saigon	do	25	12.14	1.20	0.57	0.80	2.57			0	0
68	Macan	Laguna	90	11.74	2.06	0.73	1.21	4.00			0	0
69	Kinanda	do	90	12.34	1.47	0.74	1.11	3.32			0	0
70	Magsalit	do	87	12.07	2.02	0.73	1.30	4.05			0	0
71	Binerto	do	95	11.52	2.39	0.77	1.17	4.33			0	0
72	Mangasa	do	90	11.97	1.84	0.76	1.26	3.86			0	0
73	Sinaguing	do	96	11.96	2.16	0.63	1.19	3.98			0	0
74	Guinangang	do	90	12.60	1.72	0.69	1.22	3.63			0	0
75	Sinan Jose	do	87	12.08	1.89	0.62	1.30	3.81			0	0
76	Dinagat	do	88	12.43	2.14	0.71	1.28	4.13			0	0
77	Sinadyaya	do	89	12.32	1.76	0.64	1.28	3.68			0	0
78	Sinandaang	do	98	11.59	1.80	0.58	1.09	3.47			0	0
79	Piniro	do	80	12.59	1.74	0.63	1.25	3.62			0	0
80	Kalibo	do	86	11.92	1.87	0.64	1.16	3.67			0	0
81	Scout rice, QMC	Pampanga	92	11.08	1.79	0.76	1.18	3.73			0	0
82	Magsanbay	Laguna	88	11.81	2.20	0.86	1.40	4.46			0	0
83	Piniro	do	89	12.40	2.35	0.82	1.24	4.41			0	0
84	Kalibo	do	85	12.94	1.87	0.76	1.33	3.96			0	0
85	Mangasa	do	90	12.40	2.06	0.82	1.40	4.28			0	0

86	Binirhen	do	91	12.03	2.03	1.79	1.38	4.20			0	0
87	Kinanba	do	92	11.88	1.94	0.78	1.31	4.03			0	0
88	Pino	do	93	11.25	2.77	0.88	1.40	5.05			0	0
89	Tiniaong	do	92	12.25	2.31	0.68	1.21	4.20			0	0
90	Binagat	do	90	12.59	2.31	0.73	1.29	4.33			0	0
91	Pulapot	do	88	12.19	2.16	0.80	1.28	4.24			0	0
92	Choice rice, QMC	Rizal	3	11.30	0.67	0.47	0.56	1.70			100	2.08
93	Bulao	Negros	10	11.77	0.26	0.55	0.67	1.48			100	1.93
94	Cabagbag	do	14	11.99	0.41	0.43	0.55	1.39			100	2.68
95	Tuhao	do	9	12.75	0.31	0.38	0.54	1.23			100	2.94
96	Mayoro	do	9	11.89	0.29	0.35	0.57	1.21			100	2.56
97	Bagonhon	do	10	12.31	0.39	0.53	0.78	1.70			100	2.04
98	Inantipolo	do	8	12.64	0.61	0.50	0.68	1.79			75	1.21
99	Cabunlay	do	10	11.93	0.41	0.53	0.76	1.70			100	1.62
100	Dalikat	Laguna	90	10.86	1.78	0.85	1.39	4.02			0	0
101	Dinagat	do	90	11.09	2.34	0.75	1.29	4.38			0	0
102	Inintiw	do	90	11.87	2.25	0.89	1.41	4.55			0	0
103	Inabaca	do	90	11.08	1.79	0.86	1.38	4.03			0	0
104	Initlog-dalog	do	88	11.18	2.26	0.85	1.29	4.40			0	0
105	Kinanba	do	91	11.19	2.28	0.83	1.36	4.47			0	0
106	Magsampay	do	90	10.65	1.58	0.82	1.39	3.79			0	0
107	Pino	do	90	11.58	2.86	0.82	1.90	3.58			0	0
108	Piniro	do	90	11.29	2.34	0.81	1.26	4.41			0	0
109	Tiniaong	do	95	11.27	2.37	0.82	1.34	4.53			0	0
110	Melmel	Nueva Vizcaya	25	12.53	0.75	0.55	0.80	2.10			75	1.37
111	Langlay	do	10	12.11	0.93	0.57	0.89	2.39			75	1.07
112	Daluson	do	50	11.87	1.29	0.58	0.94	2.81			0	0
113	Santo Tomas	do	20	12.79	0.92	0.51	0.87	2.30			75	1.26
114	Maraliza	do	50	11.82	1.30	0.60	1.14	3.04			0	0
115	Tiriter	do	15	12.52	0.75	0.43	0.81	1.99			75	1.10
116	Mabolo	do	75	12.52	1.49	0.62	1.08	3.19			0	0
117	Ganado	do	30	11.88	1.27	0.48	0.66	2.41			50	0.64
118	Mambaboring	do	24	11.92	0.99	0.51	0.75	2.25			75	1.05
119	Monson	do	45	12.12	1.27	1.58	0.86	2.71			0	0
120	Gindao	Leyte	38	7.42	1.37	0.62	1.06	3.05			0	0

TABLE 1.—*Chemical analyses of various rices and results of feeding same to pigeons*—Continued.

No.	Name.	Locality.	Pericarp remaining.	Chemical analysis.							Result of feeding.	
				Moisture.	Fat.	Phosphorus pentoxide.	Ash.	Total.	Nitrogen.	Amidonitrogen.	Beriberi.	Beriberi factor.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	
121	Birilbon	Leyte	85	6.07	2.17	0.74	1.20	4.11			0	0
122	Porikit	do	40	8.44	1.18	0.66	1.14	2.98			0	0
123	Cabting	do	50	8.40	1.55	0.81	1.38	3.74			0	0
124	Misamis	do	77	7.08	1.36	0.84	1.54	3.74			0	0
125	Kinutong	do	66	9.79	1.52	0.56	1.02	3.10			0	0
126	Kinanpay	do	75	8.70	1.53	0.74	1.21	3.48			0	0
127	Aglipay	do	20	7.39	1.24	0.66	1.10	3.00			0	0
128	Cabud-bud	do	90	6.71	1.92	0.91	1.88	4.71			0	0
129	Lubane	do	80	6.48	1.56	0.58	1.06	3.20			0	0
130	Bungkol	Ilocos Norte	30	10.00	1.07	0.51	0.82	2.40			0	0
131	Malikat	do	10	9.92	0.88	0.51	0.56	1.95			50	1.91
132	Dalusan	do	5	9.94	0.99	0.45	0.66	2.10			100	1.41
133	Begsang	do	75	9.85	1.90	0.77	1.20	3.87			0	0
134	Capitana	do	20	9.96	1.21	0.54	0.87	2.62			75	1.41
135	Mudson	do	25	9.71	1.17	0.56	0.83	2.56			0	0
136	Macabiag	do	20	10.78	1.13	0.55	0.86	2.54			0	0
137	Tenido	do	5	9.70	0.88	0.51	0.73	2.12			100	2.22
138	Galiano	do	55	9.78	1.54	0.71	1.05	3.30			0	0
139	Tadioc	do	50	9.65	1.26	0.57	0.87	2.70			0	0
140	Kinastano	Batangas	15	10.23	0.92	0.56	0.78	2.26			25	0.32
141	Inabaka	do	10	10.20	0.76	0.53	0.69	1.98			0	0
142	Binagat	do	12	10.32	0.84	0.54	0.94	2.32			100	1.58
143	Pinursige	do	50	9.71	1.11	0.53	0.83	2.47			0	0
144	Nagdame	do	20	9.39	1.00	0.55	0.80	2.35			0	0
145	Kinawayan	do	40	9.94	0.99	0.58	0.89	2.46			25	0.31

146	Aguyod	do	30	9.70	1.27	0.53	0.90	2.70			0	0
147	Tampukoy	do	20	9.93	1.04	0.53	0.79	2.36			0	0
148	Kinandang pute	do	10	9.78	0.59	0.51	0.83	1.93			75	1.34
149	Kinandang pula	do	40	10.07	0.96	0.63	1.07	2.66			0	0
150	Scout rice, QMC	Pampanga	88	12.52	1.36	0.76	1.07	3.19			0	0
151	Cotsian	Iloilo	33	10.62	1.15	0.54	0.67	2.36			0	0
152	Calubad	do	28	8.94	0.99	0.56	1.03	2.58			25	0.71
153	Cabonlong	do	35	9.21	1.12	0.57	0.98	2.61			75	1.83
154	Eninian	do	25	9.85	1.15	0.56	0.97	2.68			25	0.39
155	Macan arabon	do	10	10.71	1.10	0.60	0.70	2.40			25	0.96
156	Macan quinatia	do	75	9.58	1.40	0.59	1.00	2.99			0	0
157	Macan kinalway	do	30	10.72	1.09	0.62	0.97	2.68			0	0
158	Tahao	do	45	9.62	1.68	0.66	0.95	3.29			0	0
159	Macan tabao	do	75	11.08	1.32	0.65	1.09	3.06			0	0
160	Hinipon	do	12	10.16	1.06	0.55	0.71	2.32			25	0.27
161	Magsalit	Bulacan	55	11.32	1.80	0.71	1.03	3.54			0	0
162	Macan puti	do	65	10.40	1.84	0.54	1.16	3.54			0	0
163	Macan Obando	do	45	10.75	1.83	0.68	1.04	3.55			0	0
164	Macan tago	do	40	10.72	1.49	0.65	0.89	3.03			0	0
165	Macan cumpul	do	45	11.60	1.39	0.63	0.94	2.96			0	0
166	Dinumero	do	95	10.68	1.86	0.71	0.78	3.35			0	0
167	Tinacloban	do	35	9.95	1.50	0.62	0.95	3.07			0	0
168	Binuhangin	do	20	8.82	1.40	0.54	0.95	2.89			0	0
169	Sinanduyong	do	95	9.20	1.83	0.71	1.24	3.78			0	0
170	Malagkitna puti	do	85	8.99	2.10	0.83	1.28	4.21			0	0
171	Solo	Java	90	8.76	1.54	0.58	0.74	2.86			0	0
172	Rogol	do	95	7.99	2.10	0.65	1.09	3.84			0	0
173	Si rosaki	do	90	8.72	1.65	0.68	1.13	3.46			0	0
174	Semas	do	95	8.46	1.51	0.59	0.87	2.97			0	0
175	Djalen	do	90	8.50	1.35	0.60	0.75	2.70			0	0
176	Songsan	do	90	8.17	1.26	0.55	0.87	2.68			0	0
177	Karang serang	do	90		1.26	0.68	1.07	3.01			0	0
178	Baok	do	95	10.62	1.63	0.56	0.72	2.91			0	0
179	Merivimankotti	do	90	10.62	1.59	0.64	0.88	3.11			0	0
180	Gedangan	do	98	10.35	1.50	0.55	0.92	2.97			0	0

TABLE 1.—*Chemical analyses of various rices and results of feeding same to pigeons*—Continued.

No.	Name.	Locality.	Pericarp remaining.	Chemical analysis.							Result of feeding.	
				Moisture.	Fat.	Phosphorus pentoxide.	Ash.	Total.	Nitrogen.	Amido-nitrogen.	Beriberi.	Beriberi factor.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	
181	Murmuray	Tarlac	85	10.85	2.02	0.69	0.96	3.67			0	0
182	Ubanan	do	80	10.05	1.92	0.59	0.95	3.44			0	0
183	Ramai	do	60	10.62	1.34	0.63	1.01	2.98			0	0
184	Bulalake	Cotabato	45	10.82	1.05	0.58	0.87	2.50			75	0.37
185	Badyong	do	20	10.86	0.97	0.56	0.80	2.33			0	0
186	Balasang	Ilocos Norte	65	8.67	1.47	0.53	0.86	2.86			0	0
187	Curapo	do	80	8.00	1.59	0.69	1.16	3.44			0	0
188	Danacal	do	88	8.57	1.41	0.59	1.08	3.08			0	0
189	Duanaig	do	70	8.51	1.66	0.66	1.03	3.35			0	0
190	Caraygay	do	85	8.57	1.47	0.59	0.88	2.94			0	0
191	Malaka	do	35	8.92	1.53	0.56	0.79	2.88			0	0
192	Maracatuday	do	70	8.63	1.28	0.56	0.95	2.79			0	0
193	Malaka	do	60	8.19	1.64	0.51	0.80	2.95			0	0
194	Matanobong	do	75	8.73	1.49	0.55	0.85	2.89			0	0
195	Matayesa	do	80	8.55	1.67	0.60	0.92	3.19			0	0
196	Murmuray	do	85	8.77	1.89	0.63	1.04	3.36			0	0
197	Santa Maria	do	80	8.03	1.69	0.67	1.20	3.36			0	0
198	Glutinous rice No. 1	Hongkong	0	9.94	0.34	0.27	0.49	1.10			100	4.00
199	Glutinous rice No. 2	Shanghai	0	10.02	0.57	0.31	0.45	1.33			100	2.27
200	Glutinous rice No. 3	Hongkong	0	9.68	0.59	0.25	0.48	1.32			100	3.03

arranged in sequence from the lowest to the highest and charted, together with the beriberi-producing factor for each rice (figs. 1 to 8).

II. DISCUSSION

1. The beriberi factor.—Our figures for the beriberi factor cannot be taken as an accurate quantitative index of the beriberi-producing potentialities of these rices, as is evidenced by the irregularities of the beriberi line in the charts. Nevertheless, the method of arriving at this factor is believed to be correct, and the inaccuracy is chiefly due to the fact that only a limited number of birds of various ages could be used in these experiments with the cage space and birds at our disposal. Had it been possible to feed twenty birds of the same age on each rice, this factor would have been more accurate, since the undoubted variation in individual susceptibility to polyneuritis would have exerted less influence on the result, and the beriberi line on the charts would have been much smoother.

Whatever the quantitative error, it is obviously the same for all of the chemical constituents of each rice used, and therefore this factor may be employed as a reliable guide to the determination of the most satisfactory chemical index of the beriberi-preventing rices. By viewing the charts it will appear that no matter whether ash, phosphorus pentoxide, or fat is used as indicator, the character of the curve is the same. At the lowest figures shown by the chemical analyses, the incidence of polyneuritis is high and, as the chemical figures rise, the line indicating the amount of polyneuritis drops. An irregular zone is thus reached for each chemical index where some rices produced polyneuritis and other rices afforded complete protection. Finally, with each index a figure is reached at which the beriberi factor drops to zero, and remains there for every rice having that particular quantity or more. Obviously that chemical index in which the irregular zone is reduced to a minimum will be the best.

2. Amount of pericarp remaining on the grain as determined by staining and inspection.—The staining-and-inspection method is quite exact for completely polished rices having none of the external layers remaining and for rices having these external layers practically intact. For rices having from 5 to 50 per cent of their external layers the method cannot be called exact, and is probably subject to at least a 10 per cent error. That is, it would probably be impossible to distinguish between rices

having in one case 45 per cent and in another case 50 per cent pericarp; but rices having 30 and 50 per cent, respectively, can be readily distinguished, and differences bewteen 40 and 50 per cent are fairly noticeable.

It is also possible that all of the vitamin is not always contained exclusively in the external layers of the rice, and that most highly milled rices still contain traces of vitamin. This possibility is strongly suggested by the fact that pigeons fed on a synthetic diet of cornstarch 90 per cent, egg albumen 8 per cent, salt mixture 1 per cent, and cod-liver oil 1 per cent developed polyneuritis much faster than when fed on the most highly milled rices. Thus, in one such experiment, all four pigeons developed polyneuritis, in 12, 14, 18, and 18 days, respectively, giving a beriberi factor of 6.4, higher than the highest (4.0) obtained from the use of any rice in our series. McCarrison and Norris arrived at the same conclusion, since washing or autoclaving the most highly polished rices increased their capacity to produce polyneuritis. If traces of vitamin occur as a rule in such highly milled rices, certain exceptional samples may contain unusually large amounts, sufficient to prevent the development of beriberi.

Such unusual rices are undoubtedly the cause of some of the irregularities in our charts and may be responsible for the doubts that have arisen in the minds of some sanitary authorities concerning the validity of the theory that beriberi is caused by a deficiency arising from the consumption of highly milled rice.

Admitting these sources of error, the fact still remains that, in the examination of the two hundred rices of this series by this method, no rice having 50 per cent or more of the external layers of the grain produced polyneuritis when fed to pigeons (fig. 1). If this were taken as a standard it would have excluded seventeen rices that afforded complete protection, as follows: One rice out of fifteen having only 10 per cent; five rices out of seventeen having 20 per cent; two rices out of five having 25 per cent; three rices out of five having 30 per cent; two rices out of three having 35 per cent; three rices out of four having 40 per cent; and four rices out of five having 45 per cent. By consulting the charts it will be seen that this method of determining a rice that will prevent beriberi is more accurate than either ash, phosphorus pentoxide, or fat used as an index. This is a complete confirmation of previous ex-

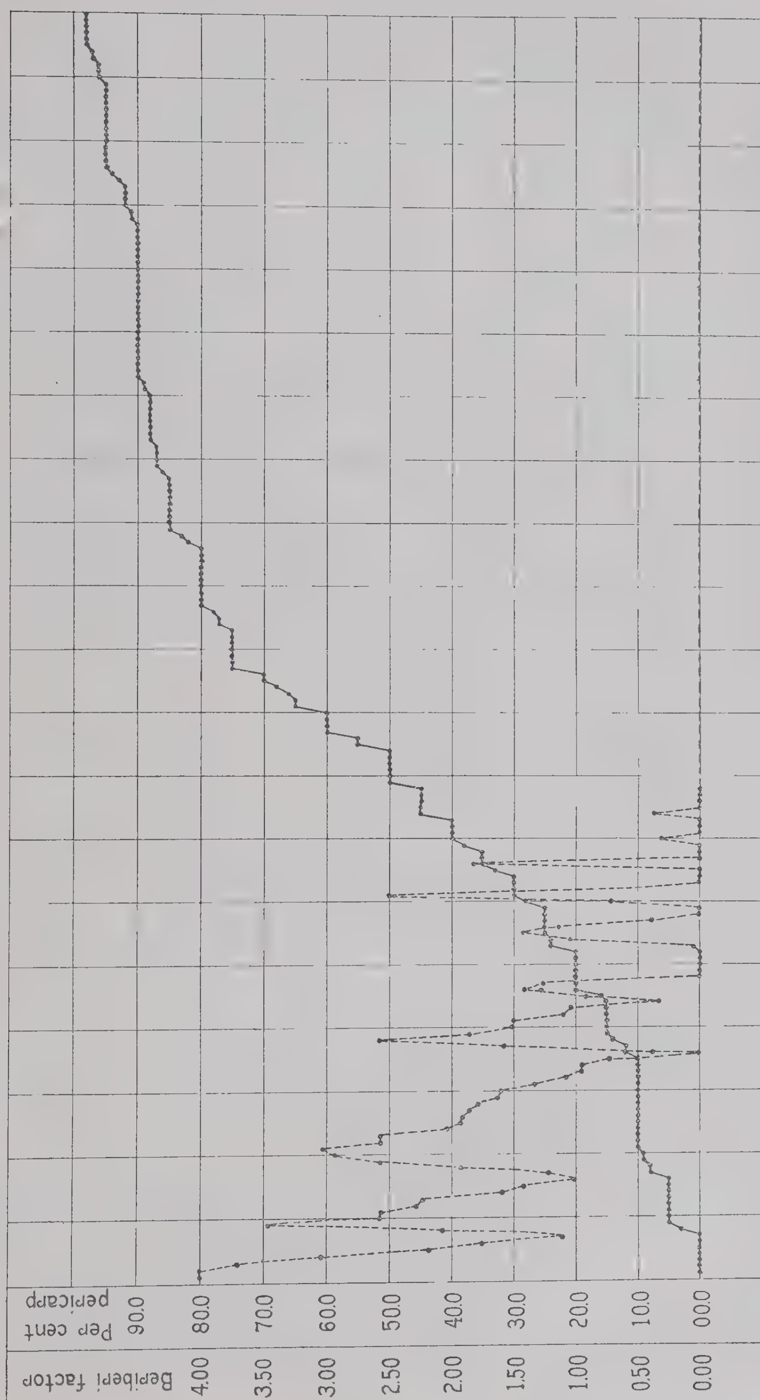

FIG. 1. Percentage of the external layers of the grain remaining on each rice (heavy line) and the beriberi factor for the same rices (broken line).

perience, indicating that this simple inspection of rice is the best method for selecting a rice that will afford protection.

Since pigeons are so much more susceptible to polyneuritis than the human race is to beriberi, it seems possible that any rice having 30 per cent of the external layers remaining on the grain will prevent human beriberi. The rarity of beriberi when hand-pounded rice is eaten is therefore readily explainable.[4] Nevertheless, in purchasing rice for the Philippine Scouts, the endeavor has always been made to select a rice having the external layers nearly intact. Of the seven samples used in this series only one had as low as 88 per cent of the external layers, the remaining six samples ranging from 92 to 98 per cent.

This undoubtedly accounts for the uniform success in the prevention of beriberi in the Philippine Scouts since 1910, when such undermilled rice was furnished. This method is therefore to be recommended as the best and simplest for use in armies and institutions, where some experienced and responsible official can make the examination. Unfortunately, it cannot be recommended as a legal standard, because the administration of a law cannot depend entirely upon the judgment of any single individual, however skilled he may be.

According to the resolutions formulated by the sixth congress of the Far Eastern Association of Tropical Medicine, some terminology is desirable to designate these various degrees of milling. Accordingly, it is suggested that rices in the process of milling may be stained with iodine and inspected, and that those rices having from 0 to 20 per cent of the external layers be called "highly milled rice;" from 21 to 49 per cent, "medium-milled rice;" and from 50 to 100 per cent, "undermilled rice." These names, besides being convenient, would correspond to the facts with regard to the incidence of beriberi. Beriberi may be expected to be prevalent when highly milled rice is used as a dietary staple. When medium-milled rice is so used, cases of beriberi may not occur at all, or may sometimes occur, but the cases will be more apt to be sporadic. When undermilled rice is used, beriberi will not occur at all.

3. Amido-nitrogen as an index.—The determination for amido-nitrogen appeared to bear no relation to the beriberi-producing

[4] Of course, beriberi may occur when hand-pounded rice is used, provided the pounding is carried to the point where a highly milled rice is produced. Of the 152 samples procured through the Bureau of Agriculture, which were all hand-pounded, 37 produced polyneuritis in pigeons.

potentialities of the rices. Some of the rices having the highest amounts of amido-nitrogen produced polyneuritis, while a number of samples having no amido-nitrogen afforded complete protection. This chemical estimation was discontinued after fifty samples were tested, of which thirty-five were in this series. The actual figures, with the results of feeding, are included in Table 1.

4. Ash as an index.—No polyneuritis occurred on any rice having at least 1.05 per cent of ash. However, if this were taken as a standard, it would have excluded not only all the rices that produced polyneuritis, but also fifty-eight rices that afforded complete protection. The zone of irregularity covered ninety-six rices, or almost half of the entire number (see fig. 2).

5. Phosphorus pentoxide as an index.—No polyneuritis occurred on any rice having at least 0.62 per cent phosphorus pentoxide. This standard would have excluded forty-five rices that afforded complete protection. The irregular zone was also very wide, including eighty-six rices (see fig. 3). It will thus be seen that the phosphorus pentoxide standard is better than the ash, but is not nearly so good as the fat standard. It was evident that certain highly milled and beriberi-producing rices might contain a very high percentage of phosphorus; forty-three samples that produced polyneuritis contained 0.4 per cent or more phophorus pentoxide; twenty-seven samples contained 0.5 per cent or more phosphorus pentoxide; and two samples contained, respectively, 0.60 and 0.61 per cent. Allowance must be made for the fact that pigeons, known to be highly susceptible birds, were used. It is probable that some of these rices would have protected fowls, and still more probable that they would not have caused beriberi in man. Nevertheless, none of them contained 50 per cent of the external layers of the grain, and three of these rices, Nos. 26, 43, and 92, containing, respectively, 0.43, 0.49, and 0.47 phosphorus pentoxide, were the so-called "choice rice" sold by the Quartermaster, which anyone could identify at a glance as highly milled rice that would produce beriberi. It is obvious that the old standard of 0.4 per cent is too low, and that an acceptable standard must lie between 0.5 and 0.62, preferably at the higher point, since we can at least assume that no rice that protects pigeons would cause beriberi in man.

6. Fat as an index.—No polyneuritis occurred with any rice having at least 1.28 per cent of fat or more. If taken as standard, this would have excluded twenty-five rices that afforded com-

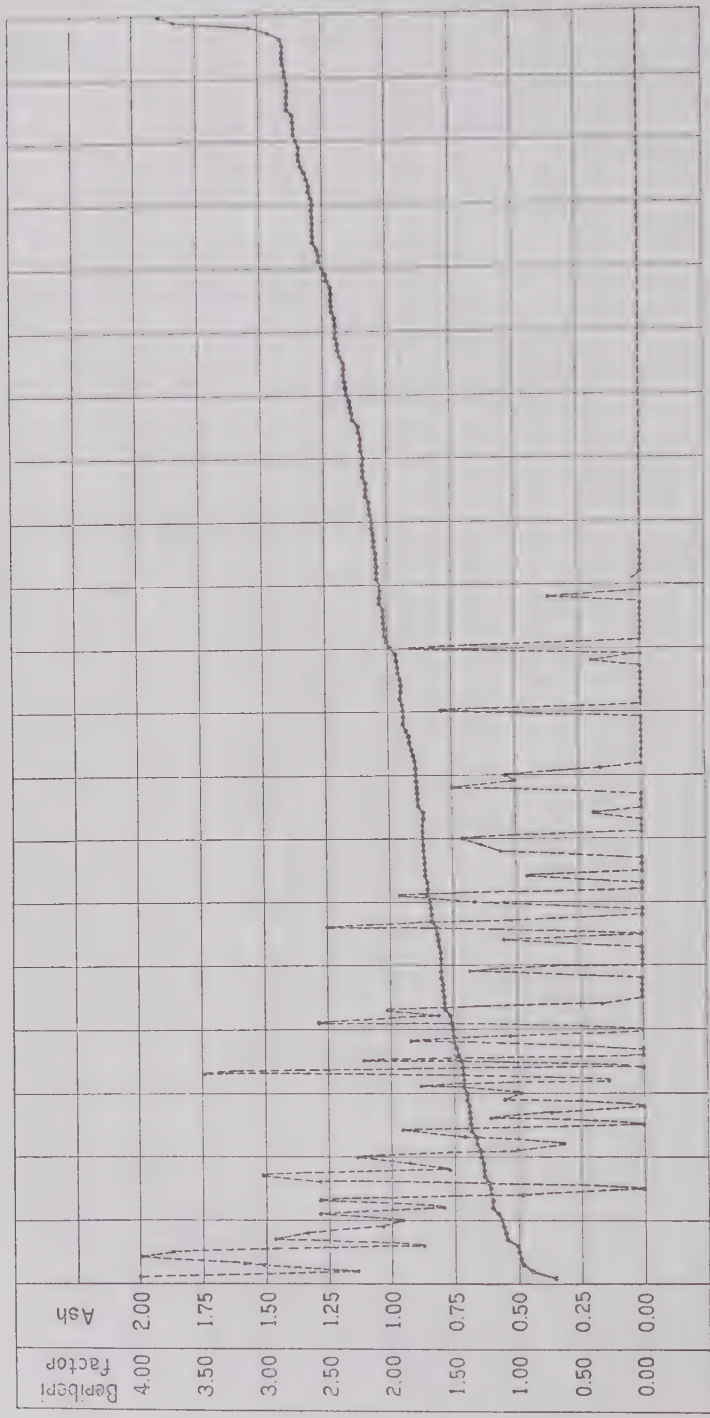

FIG. 2. The percentage of ash and the beriberi factor for each rice.

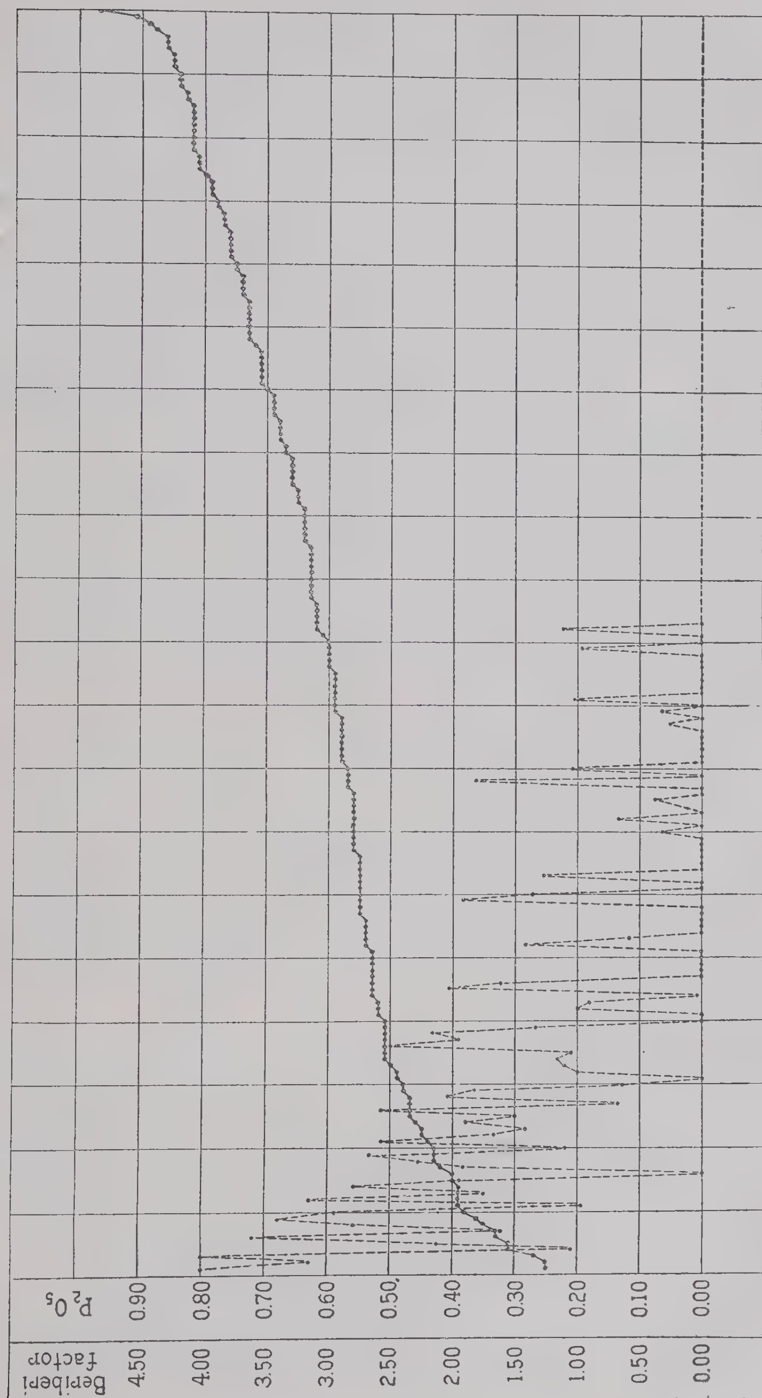

FIG. 3. The percentage of phosphorus pentoxide (P_2O_5) and the beriberi factor for each rice.

plete protection. The zone of irregularity included fifty-four rices (fig. 4). It is clear therefore that the percentage of fat would constitute a better index for a beriberi-preventing rice than the ash or the phosphorus pentoxide.

A satisfactory standard should exclude all rices that produce beriberi and should exclude none, or at least very few, that afford complete protection. Neither the ash, the phosphorus pentoxide, nor the fat fulfills these requirements. There remains the possibility that some combination of these three chemical determinations would be better than either one alone; for, when a highly milled rice contains an unusually high percentage of phosphorus, it is possible that either the mineral salts or the fat may be low, and thus the irregularities of any single determination would be corrected.

7. Phosphorus pentoxide plus ash.—The percentage of phosphorus pentoxide and ash were added and the total so obtained charted as before. No rice containing a total of 1.70 or more phosphorus pentoxide plus ash produced polyneuritis. This standard would have excluded forty-three rices that protected, and the zone of irregularity included eighty-four rices (fig. 5). This combination is evidently very little better than phosphorus pentoxide alone.

8. Phosphorus pentoxide plus fat.—When these were totalled and charted, it was found that no rice having 1.77 per cent or more of combined phosphorus pentoxide and fat produced polyneuritis in pigeons. This standard would have excluded only fourteen rices that afforded protection, and the zone of irregularity included forty rices (fig. 6). This is a distinct improvement on the fat alone, and it is evident that some of the irregularities have been corrected by the use of this combined standard.

9. Phosphorus pentoxide plus fat plus ash.—The percentages of these three ingredients were added and the totals charted. No rice having a total of 2.70 or more produced any polyneuritis when fed to pigeons. If this were used as a standard, only thirteen rices that afforded complete protection would be excluded. The zone of irregularity included only thirty-nine rices (fig. 7).

10. Two fat plus phosphorus pentoxide.—Since the fat evidently formed the best single standard, the possibility was considered that more irregularities might be corrected if the fat were given a greater weight. For this purpose, the per-

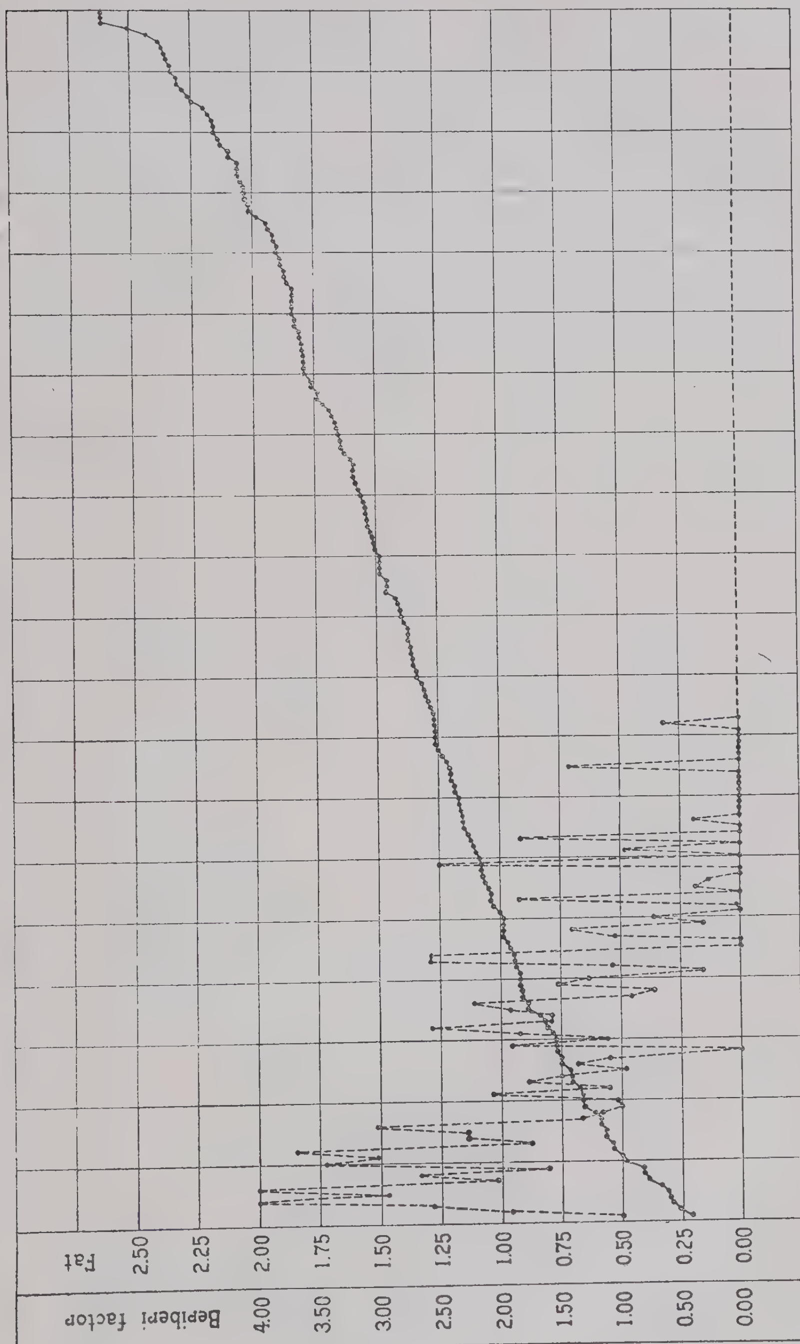

FIG. 4. The percentage of fat and the beriberi factor for each rice.

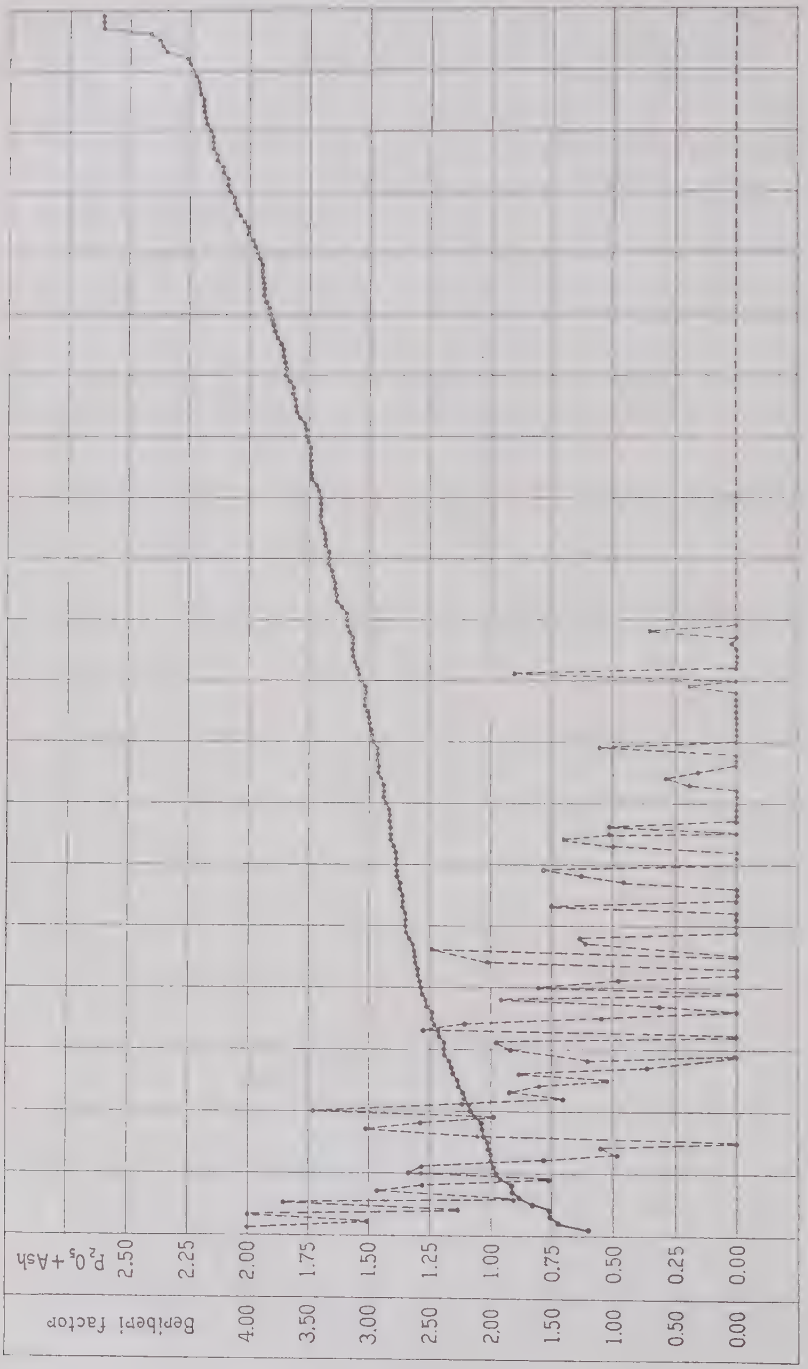

FIG. 5. The combined percentages of phosphorus pentoxide (P_2O_5) and ash in relation to the beriberi factor.

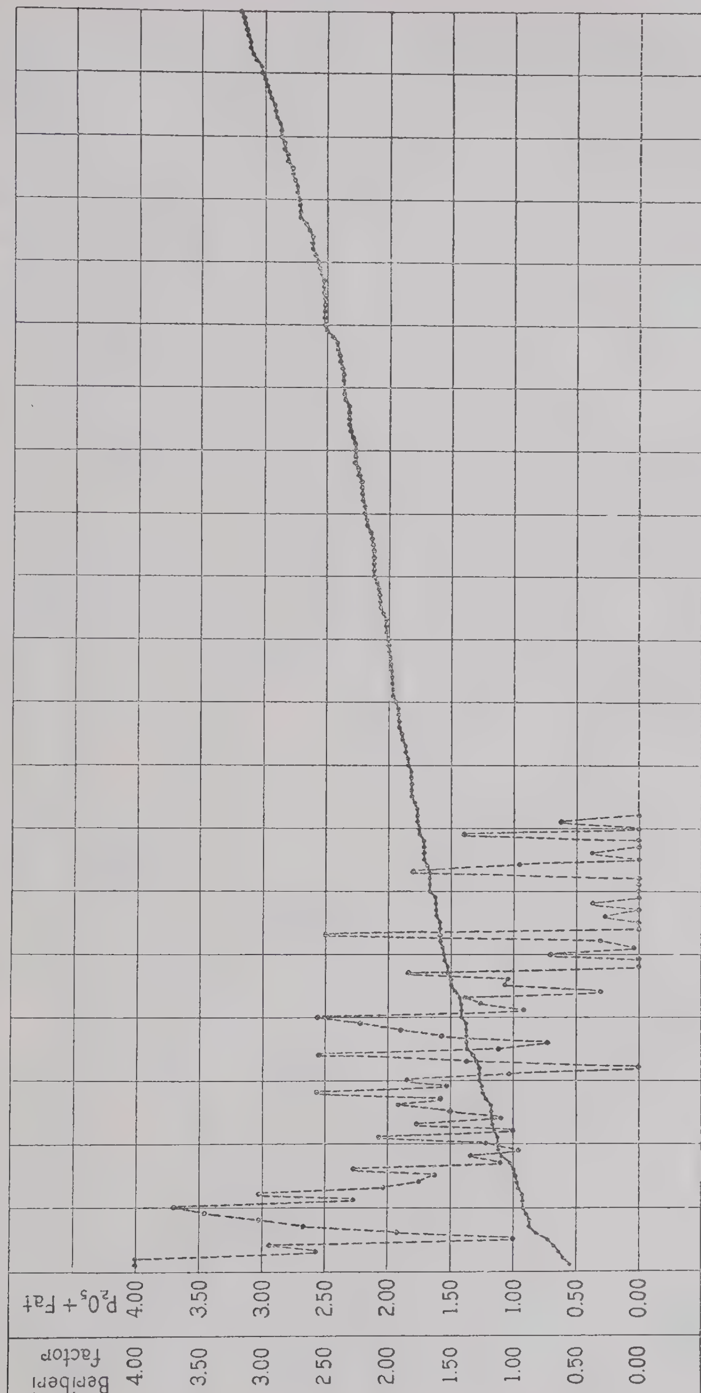

FIG. 6. The combined percentages of phosphorus pentoxide (P_2O_5) and fat and the beriberi factor for each rice.

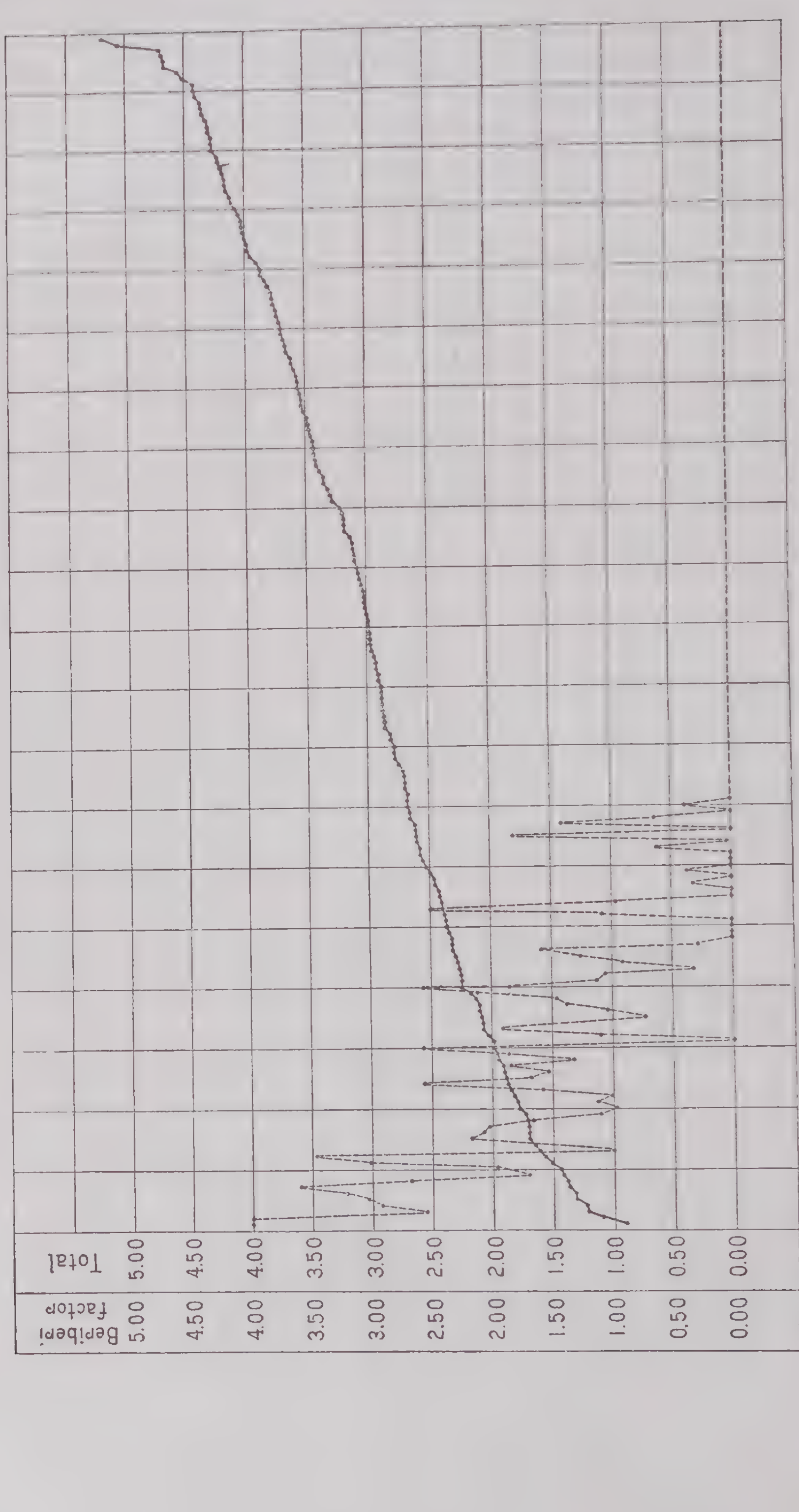

FIG. 7. The combined percentages of phosphorus pentoxide (P_2O_5) and total ash and the beriberi factor for each rice.

centage of fat was doubled and added to the percentage of phosphorus pentoxide. No rice containing a total of 3.07 or more, so figured, produced polyneuritis. This standard would have excluded seventeen rices that protected, and the zone of irregularity included forty-three rices (fig. 8). This standard was evidently somewhat less accurate than the simple addition of the percentages of fat and phosphorus pentoxide.

11. Two fat plus 1 phosphorus pentoxide plus 1 ash.—The percentage of fat was doubled and added to the percentage of phosphorus pentoxide and ash. No rice having a total of 3.94 or more, so computed, produced polyneuritis. If this were used as a standard, thirteen rices that afforded protection would be excluded, and the zone of irregularity included forty-four rices. A standard derived by such a computation is obviously not so good as the simple total of phosphorus pentoxide, fat, and ash, which is the best standard.

The selection of the most suitable index.—While the total of phosphorus pentoxide, fat, and ash placed at 2.70 was unquestionably the best chemical index for this series of two hundred rices (excluding thirteen rices that protected), it was only slightly better than the sum of the phosphorus pentoxide and fat when placed at 1.77 (excluding fourteen rices that protected). Simplicity is also worthy of consideration, since the more complex the chemical procedure, the greater the possibility of technical error and the more time-consuming the determination of the index of a given rice. Moreover, the ash is the poorest single index, and varies more than any other constituent, since it depends chiefly upon the amount of mineral salts in the soil. For these reasons the standard of 1.77 phosphorus pentoxide plus fat would seem the more desirable.

Of the one hundred twenty-nine rices containing this amount or more of phosphorus pentoxide plus fat that afforded complete protection to pigeons, only one (No. 34) contained as little as 0.4 per cent phosphorus pentoxide. This standard may therefore be improved by adding the proviso that the amount of phosphorus pentoxide must be at least 0.4 per cent.

Using the percentage of phosphorus pentoxide alone as a standard, all rices having at least 0.62 phosphorus pentoxide afforded protection. Of the fourteen rices that afforded complete protection having less than 1.77 phosphorus pentoxide plus fat three, Nos. 157, 149, and 54, had, respectively, 0.62, 0.63, and 0.64 phosphorus pentoxide. The standard of phosphorus

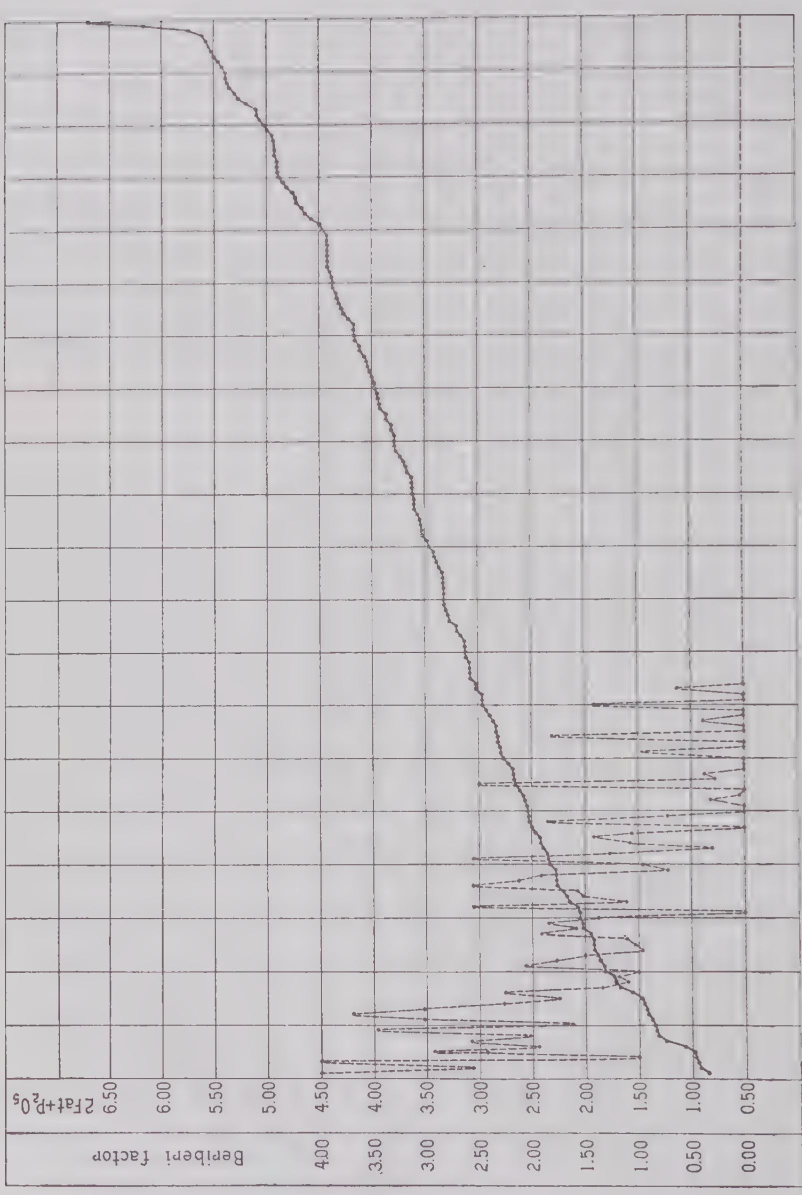

FIG. 8. The percentages when the percentage of fat was doubled and added to the percentage of phosphorus pentoxide (P_2O_5) compared with the beriberi factor.

pentoxide plus fat may be further improved by a proviso including any sample of rice having at least 0.62 phosphorus pentoxide.

Three of the rices having less than 1.77 phosphorus pentoxide that protected pigeons had at least 75 per cent of the external layers of the grain and no less than 0.5 per cent phosphorus pentoxide (No. 54, 75 per cent; No. 35, 77 per cent; and No. 22, 85 per cent). The chemical standard might be improved by including any rice having at least 0.5 per cent phosphorus pentoxide and not less than 75 per cent pericarp.

The tentative standard for beriberi-preventing rice would therefore read as follows: *Any rice having 1.77 per cent of phosphorus pentoxide plus fat, but not less than 0.4 per cent phosphorus pentoxide; or any rice having not less than 0.62 phosphorus pentoxide; or any rice having not less than 0.50 per cent phosphorus pentoxide and with at least 75 per cent of the external layers of the grain remaining.*

This standard may be considered as absolutely safe for man, in view of the fact that such rices afforded complete protection to pigeons when used as an exclusive diet. Moreover, this standard excluded only nine rices that afforded protection out of a total of two hundred, or 4.5 per cent, and the examination required would be little more difficult and no more time-consuming than the estimation of phosphorus pentoxide alone. It is believed that this is the best chemical standard that can be devised in the absence of any direct method of estimating the exact amount of antineuritic vitamin, and it is accordingly submitted as a basis for discussion.

III. THE EFFECT OF DEFECTS IN THE STORAGE OF RICE AND IN ITS PREPARATION FOR FOOD ON THE PROPOSED STANDARD

The determination of a standard for beriberi-preventing rice is but the first part of the solution of the administrative problem. The prevention of beriberi in native populations depends not only upon the provision of an adequate beriberi-preventing rice, but almost equally upon the provision of facilities for the proper storage of such rice and upon correct methods of its preparation for food.

In order to determine the effect of washing rice, ten samples of rice were analyzed for their phosphorus pentoxide content, washed, and analyzed again after washing. The method of washing was a follows: The rice was placed in a saucepan and

washed with running water until the water came away clear, which usually required about five minutes. The rice was then dried with an electric fan until all excess water was evaporated. The rice was not handled or stirred during the washing. The results of this experiment are shown in Table 2, and it will be seen that in every case the phosphorus pentoxide content was greatly reduced. Calculated on a dry basis, all ten samples originally contained at least 0.4 per cent phosphorus pentoxide, while after washing no sample contained 0.4 per cent, the average loss for the ten samples being 0.25 per cent phosphorus pentoxide. Presumably the vitamin content of these rices was similarly reduced. When excess water is used in cooking and this is strained off, a further loss of phosphorus pentoxide and of vitamin occurs.

TABLE 2.—*Comparative phosphorus pentoxide content of washed and unwashed rice.*

Sample identification No.	Before washing.			After washing.			Phosphorus pentoxide content.
	Moisture.	Calculated from sample as received.	Calculated from dry basis (*a*).	Moisture.	Washed samples, air dried.	Calculated from dry basis (*b*).	Difference between (*a*) and (*b*).
	P. ct.	P_2O_5 *p. ct.*	P_2O_5 *p. ct.*	*P. ct.*	P_2O_5 *p. ct.*	P_2O_5 *p. ct.*	*P. ct.*
1	11.15	0.369	0.415	9.41	0.160	0.177	0.238
2	11.00	0.402	0.451	8.73	0.187	0.204	0.247
3	11.08	0.371	0.417	9.73	0.181	0.201	0.216
4	11.56	0.426	0.482	8.23	0.191	0.208	0.274
5	10.97	0.358	0.402	10.01	0.172	0.191	0.211
6	12.07	0.402	0.457	8.33	0.171	0.187	0.270
7	11.59	0.420	0.475	9.24	0.174	0.192	0.282
8	11.46	0.396	0.447	9.92	0.157	0.174	0.273
9	11.91	0.414	0.470	8.07	0.172	0.187	0.283
10	11.54	0.408	0.461	9.81	0.230	0.255	0.206

Previous writers, including Schüffner and Kuenen and McCarrison and Norris, have shown that prolonged washing or soaking of the rice, prior to cooking, extracts and removes a considerable portion of its vitamin, and that an originally beriberi-preventing rice may be thus converted into a beriberi-producing rice. This is what would be expected, in view of the fact that the antiberiberi vitamin is very freely soluble in water, and there would be no necessity for emphasizing this point except for the fact that ignorance of this possibility has frequently caused confusion of ideas concerning the etiology of beriberi and has

thrown suspicion upon the validity of a standard for beriberi-preventing rice.

At the 1912 meeting of the Far Eastern Association of Tropical Medicine at Hongkong(3) an instance was related of two neighboring institutions, a monastery and a convent, that had been supplied with the same rice. There was no beriberi in the monastery, but the disease was prevalent in the convent. We were later informed by Dr. Victor G. Heiser that on investigation it was found that the monks were not very particular about washing their rice, but that the nuns, with true feminine insistence upon cleanliness, washed their rice very thoroughly, and that this simple procedure was the explanation of the peculiar incidence of beriberi among the nuns.

Again, the idea has been advocated that beriberi is a place disease, depending upon some other factor than a deficient food for its production. Thus it has been found that beriberi is, and has been for many years, endemic in certain narrow tracts in India, and that the disease occurs in these endemic areas even though hand-pounded, undermilled, or parboiled rice is used.

It is by no means necessary to assume that beriberi is a place disease, or that its etiology is any different in India than in the Philippines or other countries, in order to explain such facts. Not knowing the food habits in India, we do not presume to say what they are; but it can hardly be wrong to assume that the people in such endemic regions of India are like people everywhere else in being firmly addicted to some particular diet, cooked in some special manner. It follows that, if there be any deficiency or abnormality in the diet or the method of cooking, this tendency is fixed and handed down from generation to generation, and that this alone will account for the fact that beriberi is endemic in certain localities. It seems probable that excessive washing of rice, boiling in an excessive quantity of water, or some other peculiarity in its preparation, is sufficient to account for the incidence of beriberi in these endemic areas among people using undermilled or parboiled rice.

Such erroneous food habits cannot be changed by sanitary regulations and can be changed but slowly as the result of education, and therefore they constitute one of the most serious difficulties in the eradication of beriberi in all countries. It is to obviate such difficulties as much as possible that we have recommended such a high standard for a beriberi-preventing rice. A lower standard would undoubtedly suffice if it were

not for such factors as excessive washing, pressure cooking, and other procedures that cannot be foreseen; but the standard recommended at least provides a considerable margin of safety.

At least the storage of rice is subject to sanitary regulation and deserves investigation. Long storage alone is insufficient to account for the transformation of a beriberi-preventing rice into a beriberi-producing rice. In previous papers(4, 5) it was shown that fermented undermilled rice might still be capable of preventing polyneuritis in fowls, and that undermilled rice might be kept for one year in a damp place and that, although then musty and unfit for human consumption, it still prevented the development of polyneuritis in fowls when fed as an exclusive diet. On the other hand, numerous apparently well-authenticated instances have been related in which more or less prolonged storage of undermilled rice resulted in the production of beriberi. An explanation of this discrepancy is desirable.

During the course of the experimental work on the determination of a standard for beriberi-preventing rice, it was early noted that some samples of rice were heavily infested with insects. Twenty of such heavily infested samples were selected for a special series, analyzed, and kept in cans as described previously, except that no chloroform was added to kill the insects which were permitted to live in the rice. These rices were fed to pigeons, and at the end of one hundred days, when the experiment was discontinued, the remainder of the rice was again analyzed. Samples of these rices were submitted to Mr. W. Schultze, formerly entomologist of the Bureau of Science, for identification of the insects, which he found to be—

Rice weevil, *Sitophilus oryzae* Linn.
Rice moth, *Corcyra cephalonica* Staint.
Rust-red flour beetle, *Tribolium ferrugineum* Fabr.
Granary weevil, *Sitophilus granarius* Linn.

The results of this experiment, showing the analysis of the rice before feeding and at the conclusion of the experiment, as well as the percentage of beriberi produced in pigeons and the beriberi factor are given in Table 3. It will be seen that seven rices, Nos. 1, 2, 9, 11, 15, 17, and 18, each contained originally more than 1.77 per cent phosphorus pentoxide plus fat which, in accordance with our other work, should have prevented polyneuritis; nevertheless, polyneuritis occurred with every rice used in this series. The analysis of the rice remaining at the end of one hundred days showed that in no case was the content

of phosphorus pentoxide plus fat as high as it was at first, nor was it in any case as high as 1.77 per cent, the highest total being 1.67 (No. 18) ; nor is the result changed if we take the total of phosphorus pentoxide, fat, and ash. Again, seven rices contained originally more than 2.70, whereas at the conclusion of the experiment the highest total was 2.34 (No. 1).

As the result of the depredations of insects, an average total of 2.61 was reduced to 1.71, or an average loss for each sample of rice of 0.89 per cent phosphorus pentoxide plus fat plus ash. Nor does this indicate the full extent of the damage, for the insects eat the outer layers of the grain most readily, so that those rices having the greatest proportion of the external layers as a rule suffered the greatest loss. Thus, sample No. 1 lost 1.45 per cent; No. 2, 1.78; No. 9, 1.80; No. 10, 1.24; No. 11, 1.85; No. 15, 0.90; No. 17, 0.86; No. 18, 0.75.

From the figures it is clear that a beriberi-preenting rice kept in storage, under such circumstances as to be subject to the depredations of insects, may frequently be converted into a beriberi-producing rice; for, as the insects eat away the external layers of the grain, an undermilled rice is in fact converted into a highly milled rice. The external layers, being the richest food supply, are evidently preferred by insects, and this accounts for the difficulty in storing undermilled rice. I was informed by the Quartermaster that choice rice (highly milled) could be stored a maximum of six months, while the undermilled rice intended for the Philippine Scouts could never be stored more than three months. The tendency for undermilled rice to become infested with insects is the main reason for the reluctance of rice wholesalers to handle such rice, and some practical method of meeting this difficulty must be forthcoming if the use of undermilled rice is to be enforced.

In some countries where milling facilities are ample, rice should be milled only as it is required for consumption, and undermilled rice should not be stored by the wholesaler for longer than a few weeks. Such a regulation will be more difficult to apply in other countries like the Philippines where the rice mills have a small capacity and, accordingly, the rice milled from day to day must be stored until a sufficient amount accumulates to make a shipment. In any case, however, long storage of rice is more a matter of convenience to the dealer than a necessity. The United States Army Quartermaster has found no difficulty in securing special orders of undermilled rice for

TABLE 3.—*Analyses of rices, before and at conclusion of the feeding experiments.*

No.	Name.	Locality.	Analysis before feeding.					Analysis after feeding.					Beriberi.	Beriberi factor.
			Moisture.	Fat.	Phosphorus pentoxide.	Ash.	Total.	Moisture.	Fat.	Phosphorus pentoxide.	Ash.	Total.		
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	
1	Scout rice	Pangasinan	--------	1.73	0.87	1.19	3.79	11.20	1.07	0.49	0.78	2.34	75	1.32
2	Apostol	Rizal	10.07	1.36	0.51	0.95	2.82	10.75	0.18	0.35	0.51	1.04	50	0.64
3	Inadhica	do	10.05	1.10	0.44	0.81	2.35	11.49	0.64	0.45	0.74	1.83	75	0.96
4	Roxas	do	10.16	1.17	0.52	0.80	2.49	11.56	0.29	0.30	0.40	0.99	50	0.56
5	Quinalibo	do	9.62	1.27	0.44	0.71	2.42	11.43	0.92	0.37	0.63	1.92	100	2.43
6	Cruz	do	10.33	1.02	0.48	0.75	2.25	11.57	0.64	0.43	0.67	1.74	100	2.63
7	Magsalit	do	9.79	1.06	0.46	0.81	2.33	11.91	0.68	0.38	0.71	1.77	100	1.53
8	Connor	do	9.93	1.00	0.50	0.90	2.40	11.28	0.66	0.47	0.83	1.96	50	1.38
9	Binarbang	Laguna	10.06	1.32	0.61	1.01	2.94	11.25	0.70	0.49	0.67	1.86	25	0.52
10	Binuhangin	do	10.28	1.01	0.60	1.46	3.07	10.74	0.53	0.53	0.77	1.83	50	0.63
11	Guinanggang	do	10.48	1.66	0.63	1.13	3.42	11.00	0.53	0.44	0.60	1.57	75	0.92
12	Minantica	Nueva Ecija	10.78	1.06	0.52	0.58	2.26	10.99	0.48	0.34	0.52	1.24	100	1.61
13	Macan cumpul	do	10.91	1.00	0.56	0.76	2.32	10.97	0.53	0.40	0.53	1.46	75	1.19
14	Macan Polo	do	10.58	1.11	0.42	0.54	2.07	10.87	0.70	0.32	0.48	1.50	75	1.41
15	Binulagsac	do	10.11	1.35	0.44	0.72	2.51	10.68	0.75	0.36	0.50	1.61	50	0.53
16	Macan aga	do	10.09	1.18	0.48	0.51	2.17	10.83	0.89	0.29	0.59	1.77	75	0.93
17	Sampaguita	do	10.55	1.32	0.68	0.87	2.87	10.84	0.72	0.49	0.80	2.01	50	0.64
18	Macan nineng	do	10.58	1.53	0.72	1.04	3.29	10.82	1.17	0.50	0.87	2.54	75	0.92
19	Macanining	Pangasinan	9.82	1.03	0.60	0.87	2.50	10.90	0.62	0.49	0.81	1.92	25	0.38
20	Cavitena	Nueva Ecija	12.40	0.76	0.59	0.75	2.10	11.43	0.48	0.44	0.75	1.67	100	2.56

the Philippine Scouts at frequent intervals, thus avoiding long storage. If undermilled rice were produced by law, dealers should be prevented by a suitable ordinance from keeping it in storage for long periods of time.

Infestation by insects may be also reduced by the enforcement of sanitary regulations in rice mills. Insects breed freely in accumulations of rice polish about such mills. An ordinance to regulate rice mills in the Philippines provides that, in every rice mill where labor is employed, all refuse, waste, and sweepings shall be removed at least once a day, and that an insanitary condition shall be deemed to exist if the rice in the process of milling, packing, storing, or transporting is not securely protected from mold and the development of weevils and beetles which destroy the mealy layer, and if the refuse, dirt, and waste products incident to the milling, storing, or transporting of rice are not removed daily; but this excellent regulation is nowhere strictly enforced.

So far as undermilled rice is concerned, even the strict enforcement of this regulation would not entirely prevent the subsequent development of insects in the sacked rice, because the grains themselves frequently carry the eggs that have been deposited upon them in the field before the rice is brought to the mill. Ottow(6) in 1915 recommended the use of carbon tetrachloride as a preservative for undermilled rice, stating that there was no objection to the use of this substance even on a large scale. For this purpose a wide-mouthed bottle or tin containing the preservative absorbed by cotton was introduced into each sack of rice. This killed the insects, had no influence on the taste or smell of the cooked rice, and it is noninflammable. So far as we are aware, this simple method has never been given a thorough trial in any other country; it is at least worthy of further consideration.

Another method that has been recommended and widely used in the United States,(7) for controlling mill insects in flour mills and grain elevators, is the use of heat. It has been found that a temperature of from 118 to 125° F., maintained for several hours to enable the heat to penetrate all the infested parts, will effectively kill all insects and insect eggs, and does not injure the grain in any way. The heat is obtained from steam pipes, and regulated by thermometers in various parts of the building. Such heat is more readily applied in the Tropics than in the United States.

One of the largest rice dealers in Manila has agreed to give this method a trial, and is fitting up a small room that can be tightly closed and heated, in which five hundred sacks can be treated at one time. If this experiment is successful, a further report will be made.

SUMMARY AND CONCLUSIONS

1. The proportion of the external layers remaining on a given rice may be determined with reasonable accuracy by simple inspection after staining with Gram's iodine solution.

2. When the rices of this series were examined in this manner, it was found that no rice having 50 per cent or more of the external layers of the grain produced polyneuritis when fed to pigeons.

3. Human beriberi can also be prevented by selecting rice in this manner, which is recommended as the best and simplest method for use in armies and institutions. It cannot be recommended as a legal standard.

4. This method may also be used during the milling process to determine the degree of milling, since it requires only several minutes to apply it.

5. It is suggested that rices in the process of milling or as sold be classified as follows:

a. *Highly milled rice.* Having from 0 to 20 per cent of the external layers.

b. *Medium-milled rice.* Having from 31 to 49 per cent of the external layers.

c. *Undermilled rice.* Having from 50 to 100 per cent of the external layers.

6. The results obtained in this study indicate that amido-nitrogen is useless as a chemical index; 1.05 per cent ash is a poor index; 0.62 per cent phosphorus pentoxide is somewhat better; and 1.28 per cent fat is the best single chemical index for a beriberi-preventing rice.

7. The chemical index proposed for beriberi-preventing rice is: *Any rice having 1.77 per cent of phosphorus pentoxide plus fat, but not less than 0.4 per cent phosphorus pentoxide; or any rice having not less than 0.62 per cent phosphorus pentoxide; or any rice having not less than 0.50 per cent phosphorus pentoxide and with at least 75 per cent of the external layers of the grain remaining.*

8. No rice of this series possessing these requirements produced polyneuritis in pigeons, and this standard excluded only nine rices out of two hundred that afforded protection to pigeons.

9. Since pigeons are so much more susceptible to the deficiency of antineuritic vitamin than is man, and since man seldom lives on rice alone, a standard that will protect pigeons will not only protect man, but also will provide a factor of safety.

10. This factor of safety is necessary if beriberi is to be eradicated, because defects in the storage of rice or in its preparation for food may materially reduce its vitamin content.

11. Of ten rice samples tested, thorough washing reduced the phosphorus pentoxide content from an average of 0.447 to an average of 0.197 per cent. Presumably the vitamin content was similarly reduced.

12. In an experiment with twenty insect-infested rices stored for one hundred days, an average total of 2.61 per cent (fat, phosphorus pentoxide, and ash) was reduced to 1.71, and seven undermilled rices that should have prevented polyneuritis were converted into highly milled rices that produced polyneuritis.

13. It therefore appears probable that the loss of vitamin during long storage of undermilled rice is caused by the depredations of insects that eat the external layers of the grain.

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ILLUSTRATIONS

Plate 1

Plate 2

TEXT FIGURES

1

2

PLATE 1.

PLATE 2.

THE ABO-ABO SOIL OF OCCIDENTAL NEGROS

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ONE PLATE AND ONE TEXT FIGURE

INTRODUCTION

At the meeting of the Philippine Sugar Association in 1926, the question regarding the abo-abo soil found in Occidental Negros was discussed with considerable interest. Abo-abo is the Visayan name for ash, and the soil is so called because the surface soil has an ashlike appearance. During the course of the discussion contradicting opinions were heard. It was claimed among other things that the main factor responsible for the unproductivity of the so-called abo-abo soil was the lack of organic matter. On the other hand, my preliminary finding, based on the results of analysis made of one sample of abo-abo soil, showed the presence of organic matter and nitrogen in considerable amounts. Because of the importance of this subject from the agricultural and the scientific viewpoints, further investigation was undertaken and the results obtained are presented herein.

PLAN OF INVESTIGATION

The present paper deals with the physical, chemical, and biological properties of abo-abo soil. It is hoped that the results from this work may give some clue to the solution of the abo-abo problem as at present found in Occidental Negros. This investigation was started in January, 1927, and has been conducted in accordance with the following plan:

A. Field study.
   1. Location of places where abo-abo soil is found.
   2. The approximate area in each locality.
   3. General study of the field, including its topography, drainage, vegetation, etc.
   4. Examination of soil formation.
   5. Collection of soil sample from each layer.
   6. History of the field, fertilization, cultivation, production, etc.

B. Laboratory studies.
   1. Physical studies.
   2. Chemical analyses (surface soil).
   3. Mechanical analyses (surface soil, subsoil, and substratum).
   4. Biological studies.

FIELD STUDIES

NATURE OF ABO-ABO SOIL

Abo-abo soil is a local name used by the hacenderos in Negros for a type of soil possessing a peculiar characteristic. Abo-abo is found in several places in Negros; the total area of this soil constitutes but a small portion of the entire sugar land of Occidental Negros. It occurs as small patches in the fields, from a fraction of a hectare to 100 hectares or more in extent; however, it is not unusual to find a hacienda of 300 hectares or more practically made up entirely of abo-abo soil.

Abo-abo is a black, loose, porous soil. In the places examined where this type occurs three distinct layers are usually found, as follows: The surface soil, about 15 to 25 centimeters deep, is black, very fine in texture, and exhibits a porous property; the subsoil, about 25 to 35 centimeters deep, is a fine light yellow sand; and the lower stratum consists of gravel and stones mixed with sand.

HISTORY OF EACH FIELD

Hacienda Alejandria, La Carlota.—The abo-abo soil portion of this hacienda covers an area of about 2 hectares. This portion is level, with efficient drainage. This hacienda has been under cultivation for several years, and the cane yields have been very poor, even with the use of fertilizers. Last year (1926), however, Mr. Luis Jalandoni, the owner, used cane varieties Badila and New Guinea 24, instead of Negros Purple as in the previous years, and he claims that a higher yield was obtained from the crop. Because of this result, he is of the opinion that the abo-abo soil problem in Occidental Negros can be solved by variety tests rather than by fertilizer application. Upon examination of the soil by digging to a depth of about 1 meter, at which point further digging met with difficulty on account of the rocky stratum, it was found that the surface soil is 10 to 16 centimeters deep. The subsoil, which is fine, yellowish sand, is 32 to 40 centimeters deep. This layer is followed by coarse gravel.

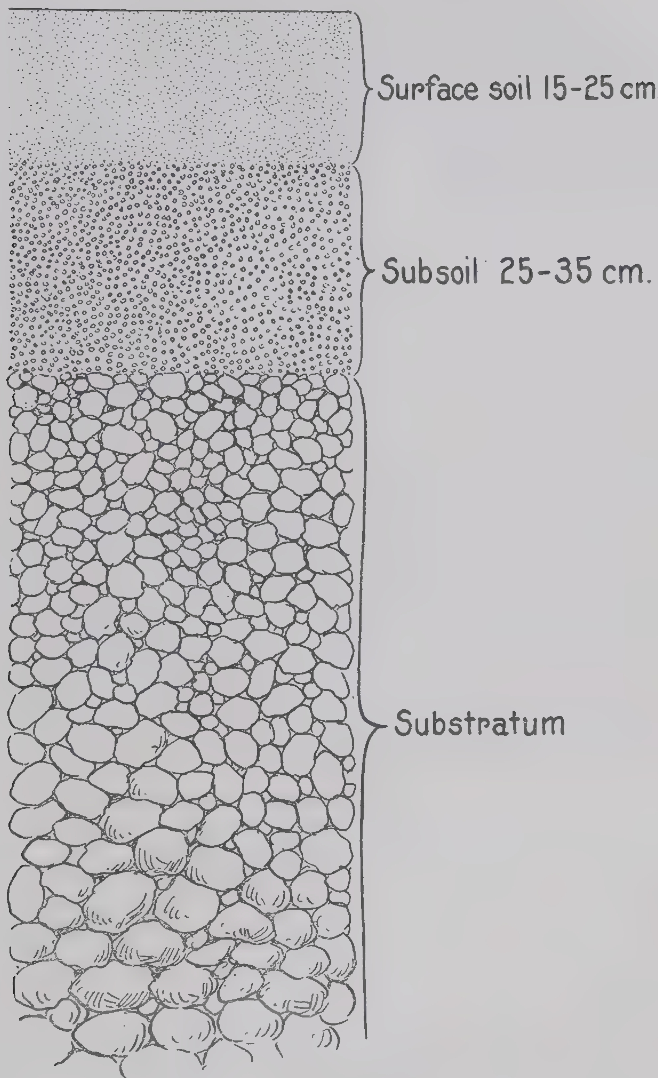

FIG. 1. Profile of abo-abo soil.

Hacienda Caman-og, La Carlota.—The abo-abo soil occurs in different sections of the hacienda. It practically covers about 4 hectares. The owner has found no means of improving this soil. From year to year the canes in this soil are stunted. The yield has been very poor, even with the use of commercial fertilizers. The soil is black, and very loose and fine in texture. The black soil extends to a depth of about 15 to 25 centimeters, and is followed by yellow sand over coarse gravel.

Hacienda Caiñaman, La Carlota.—This hacienda has about 5 hectares of abo-abo soil. It has been noticed that cane in this type of soil grows very poorly. Although fertilizers of different kinds were used yet the yields were very much lower than those obtained from the average field having another type of soil. The soil formation was examined and it was found to possess the same characteristic as that of similar soils previously examined.

Hacienda Conchita, La Carlota.—The abo-abo soil portion of this hacienda is about 25 to 30 hectares. In spite of application of fertilizers of different brands no yield has been obtained. Upon digging the soil it was found that the surface soil, which is black, and loose and fine in texture, is about 6 to 9 centimeters deep. The subsoil consists of sand and gravel and extends to a considerable depth.

Hacienda Jesusa, Bacolod, Murcia.—This hacienda has an area of about 270 hectares, 150 hectares of which are abo-abo. The whole hacienda is slightly rolling land and is all under cultivation. The good portion of the hacienda produces from 60 to 70 piculs of sugar per hectare, while the abo-abo portion gives from 10 to 15 piculs per hectare. In spite of heavy application of commercial fertilizers the abo-abo fields give very poor yields. Upon examination of the soil of the abo-abo portion it was found that the surface soil was only 7 to 9 centimeters deep and that the subsoil was of sand followed by gravel. The several borings made revealed a uniform soil formation.

Hacienda Cabangcalan, Hawaiian Philippine.—The soil of the whole hacienda is practically all abo-abo; it has been abandoned for several years, with the exception of a few hectares that are still under cultivation. The yields from the cultivated fields have been very low. Corn was tried beside cane, but the corn yield was also poor. In the uncultivated area grasses are found growing very thinly. It was found that the root system has not penetrated deeper than 4 to 5 centimeters within the surface soil. The surface soil is 15 to 20 centimeters deep; the subsoil, which is yellow sand, extends to a depth of 35 to 40 centimeters, followed by gravel. It was noticed while digging that the surface soil was dry, in spite of the fact that the subsoil was very moist.

LABORATORY STUDIES

In working with a soil of the type of abo-abo the physical, biological, and chemical properties of which are not definitely

known, it is important that a determination of these properties be made for the purpose of deciding which of the factors are directly or indirectly concerned in rendering the soil unproductive. The physical analysis will show whether the soil is a favorable medium for the growing plant and also for lower forms of life the activities of which are directly concerned in transforming the nonsoluble into available plant-food elements. The chemical analysis will show the presence and amount of the necessary elements for plant growth, as well as the presence of toxic compounds containing aluminium, iron, and manganese. These compounds have a detrimental effect on the growth of the plant and will also cause the precipitation of food elements out of soil solution, thus rendering them nonavailable for the use of the plant. The biological analysis will show the presence or absence of the proper microörganisms concerned in the process of formation of available food elements; it will also show the degree of microbiological activities. This point is very important, especially in relation to the crop-producing power of the soil, because there is a certain stage in the period of growth where the plant needs a maximum supply of food and, unless such need be supplied in time, the plant suffers.

All analyses (physical, chemical, and biological) were made in accordance with standard methods. All determinations were made in duplicate.

PHYSICAL TESTS

The results obtained from the physical tests of abo-abo soil are as follows:

Specific gravity:	
Absolute or real	1.85
Apparent	0.52
Pore space, per cent	71.90
Water-holding capacity, per cent	58.23
Rate of percolation, cubic centimeter per minute	0.3
Expansion, per cent	5.0
Rate of evaporation:	
Free water surface, cubic centimeter per minute	0.16
Soil surface, cubic centimeter per minute	0.13
Hygroscopic moisture, per cent	12.48

The above figures clearly show the peculiar characteristic of the abo-abo soil. The soil is very light, having an apparent specific gravity of 0.52, which is very low as compared with that of an average normal soil. The percentage of pore space obtained indicates that this soil is very loose, thus encouraging

excessive evaporation; the rate is 0.13 cubic centimeter per minute while the free water surface under the same conditions is 0.16 cubic centimeter per minute. The water-holding capacity, 58.23 per cent, is considered normal, when compared with the results obtained from a series of tests conducted with normal soils. The rate of percolation is high, 0.3 cubic centimeter per minute. Of course, this result is to be expected of porous soil. The rate of expansion, however, is far above that of the average soils of normal productivity.

CHEMICAL ANALYSES

The results of chemical analysis obtained from a number of determinations are the following:

	Per cent.
Total nitrogen	0.529
Soluble nitrogen	Trace
Nitrate nitrogen	Trace
Ammonia nitrogen	Nil
Total phosphoric anhydride (P_2O_5)	0.866
Total potash (K_2O)	0.602
Aluminium oxide (Al_2O_3)	20.03
Iron oxide (Fe_2O_3)	7.05
Manganese oxide (Mn_3O_4)	0.15
Acidity	0.04
Humus	23.20
Alpha, HCl insoluble	11.06
Beta, HCl soluble	12.14
Total carbon	13.19
Inorganic	0.02
Organic	13.17
Organic matter	22.98

The chemical analysis shows that abo-abo soil possesses a high potential fertility, even higher than that of most Philippine productive soils. The most essential plant food elements, such as nitrogen, phosphorus, and potassium, are present in sufficient amounts for at least normal production. The soil is found to contain considerable amounts of aluminium and iron compounds. Judging from the nature of the soil solution, which is acidic in reaction (0.04 per cent of titrable acid), part of these compounds is rendered soluble. It has been proven by various investigations that the presence of a sufficient amount of soluble aluminium and iron compounds in the soil produces a toxic effect on crops. Whether this is the case in abo-abo soil I am not in a position to say without further investigation on the subject.

According to the method of humus determination by Selman A. Waksman,[1] two forms of humus are present in abo-abo soil; the alpha, or hydrochloric acid insoluble, and the beta, or hydrochloric acid soluble. This soil was found to contain 11.06 per cent alpha humus and 12.14 per cent beta humus.

The total carbon analysis shows a small amount of inorganic carbon, which is mostly carbonate carbon, but a very high amount of organic carbon, 13.17 per cent, which indicates the presence of a great quantity of organic matter. Upon computation from the organic carbon obtained the soil was found to contain 22.98 per cent organic matter.

MECHANICAL ANALYSIS

	Per cent.
Surface soil, 15–25 centimeters:	
Coarse sand, 1–0.5 millimeter	1.0
Medium sand, 0.5–0.25 millimeter	9.9
Fine sand, 0.25–0.10 millimeter	27.6
Very fine sand, 0.10–0.05 millimeter	18.7
Silt, 0.05–0.005 millimeter	37.3
Clay, 0.005 millimeter	5.5
Subsoil, sandy, 25–35 centimeters:	
Coarse sand	22.4
Medium	29.7
Fine and very fine sand	47.9
Silt	Nil
Clay	Nil
Substratum, 35 centimeters:	
Gravel	98.0
Coarse and medium sand	2.0
Fine sand	Nil
Very fine sand	Nil
Silt	Nil
Clay	Nil

The analysis shows that the surface soil contains a very small amount of clay. From the standpoint of tillage it is one of the most desirable types of soil to work; but with regard to moisture content it may not be a good type of soil, because of its high rate of evaporation. The physical study of both the subsoil and the substratum shows that there is little or no capillary connection between the surface soil and the water below as the two lower strata are mostly sand and gravel. Under these conditions, no matter how much the yearly pre-

[1] On the origin and nature of soil organic matter or soil humus: II. Method of determining humus in the soil, Soil Sci. 22 (1926) 22.

cipitation, this type of soil will always lack available moisture as after rains the water readily percolates through the soil and is not drawn up again by capillary attraction as the surface soil dries.

BIOLOGICAL ANALYSIS

A comparative study to determine the microbiological property, especially the nitrifying power, consisted in incubating a definite amount of treated and untreated soil for thirty days under optimum moisture and temperature conditions. During the period of incubation both the moisture and the temperature were kept constant. After thirty days' incubation the soil was analyzed for nitrate nitrogen, and the amount of nitrification was computed from the nitrate nitrogen obtained as compared with the nitrogen added. The conditions under which the experiment was conducted are as follows:

Soil without treatment.
Soil treated with lime ($CaCO_3$).
Soil treated with organic nitrogenous material (copra cake).
Soil treated with organic nitrogenous material and lime.
Soil treated with inorganic nitrogenous material (ammonium sulphate).
Soil treated with inorganic nitrogenous material and lime.

Several determinations were made for each condition or set of conditions and the figures reported herein represent the average result of all the determinations for each set (Table 1).

TABLE 1.—*Results of biological analyses of abo-abo soils.*

Laboratory No.	Treatment.	Nitrate nitrogen mg. per 100 g. soil.	Added nitrogen nitrified.
			Per cent.
100–110	100 grams soil	Trace.	
120–290	100 grams soil + 0.2 grams lime ($C^{\bullet}CO_3$)	0.3011	0.06, of original nitrogen.
300–490	100 grams soil + 1.2 grams copra cake + 0.2 grams lime	0.3279	0.81
500–590	100 grams soil + 0.2 gram ammonium sulphate + 0.2 gram lime	1.454	3.46
600–690	100 grams soil + 1.2 grams copra cake	Trace.	
700–790	100 grams soil + 0.2 gram ammonium sulphate	Trace.	

When ammonium sulphate and copra cake were each applied to the soil their nitrogen content was not nitrified after thirty days' incubation under favorable moisture and temperature

conditions. When soil alone was incubated under the same favorable conditions, a very small degree of nitrification was noticed. However, with the addition of lime to the soil the nitrification process was accelerated to a small degree. For instance, the original nitrogen of the soil was nitrified 0.06 per cent, that of copra cake 0.81 per cent, and that of ammonium sulphate 3.46 per cent. The degree of nitrification of ammonium sulphate is much higher than that of copra cake, but such a result is to be expected; it simply shows that the two materials differ in the number of stages of decomposition through which they pass in the process of nitrification. Copra cake must pass through at least five stages before nitrate production is accomplished, while ammonium sulphate must pass through only three stages.

The results obtained indicate that the microbiological property of this soil is far below normal. The conversion of unavailable nitrogen is very much slower than it is in other soils, and therefore the amount of available converted nitrogen is even smaller than the minimum intake of this element by any ordinary crop.

GENERAL DISCUSSION OF RESULTS

A careful study of the results from the foregoing experiments and observations shows that one of the outstanding factors responsible in rendering the abo-abo soil unproductive is the physical property of the surface soil which encourages excessive evaporation and a high rate of percolation, in combination with the unusual soil formation of sandy subsoil and gravel substratum. The above phenomena indicate very clearly that the surface soil will always be deprived of available water. During a heavy precipitation all the excess water is being percolated below and, by virtue of the characteristic of the lower strata, this percolated water has little chance to go up and maintain the equilibrium of available water supply in the surface soil during the period of excessive evaporation, thus resulting in the permanent wilting of the crop.

From the chemical consideration it is quite unusual for such a soil as abo-abo, the total organic matter content of which is high, to exhibit a high rate of evaporation: but it should be borne in mind that there are two forms of organic matter (natural and soil organic matter), and both forms may exist in the soil at the same time. The natural organic matter consists of ani-

mal and plant residues, which when added to the soil undergo rapid decomposition, while the soil organic matter is derived from organic substances mostly from plant life and, owing to unfavorable environment conditions, it becomes mineralized and is resistant to the action of soil microörganisms for further decomposition. A soil may contain a considerable amount of total organic matter; but, if it is mostly the resistant form, the physical property of the soil with regard to the retention of moisture will not be materially improved. The low percentage of clay in abo-abo soil indicates the lack of colloidal materials which, when present, help to check the maximum loss of water from the soil.

A series of biological tests shows that the reaction of the soil hinders the activities of the different organisms concerned in the processes of decomposition for the conversion of nonavailable food elements into a state in which they become available for the plant.

SUMMARY

The results of all the tests and analyses conducted with the abo-abo soil reveal the following fundamental facts:

1. Due to the peculiar physical characteristic of the surface soil, the rate of evaporation and percolation become high, thus greatly reducing the available water supply in the surface soil for the use of the plant.

2. During the period of low precipitation and high evaporation, the available water supply in the surface soil is limited, because of the unusual formation of the lower strata—sandy subsoil and gravel substratum—which prevents the transmission of water by capillarity from below to the surface soil. Under this condition the crop suffers, not only from lack of moisture, but also from serious lack of plant food.

3. The porosity of the abo-abo soil is primarily due to the absence of a sufficient amount of colloidal materials. The presence of colloidal materials increases the retentive and absorptive power of a soil.

4. The different soil organisms concerned in the formation of available plant foods are rendered inactive by the unfavorable reaction of the soil solution present in abo-abo soil.

5. The limited water supply in the surface soil and the unfavorable soil reaction are the factors responsible for rendering any commercial-fertilizer application in abo-abo soil ineffective.

RECOMMENDATIONS

After taking into consideration the outstanding factors directly concerned with the abo-abo problem, the following recommendations are offered in the hope of improving the productive capacity of abo-abo lands:

1. During the wet season of the year the land should be seeded with legumes, especially mongo, cowpeas, or soy bean. When the plants begin to flower, ground limestone should be applied at the rate of 1 to 2 tons per hectare; the legumes should then be plowed under, the plowing to be as deep as possible. With the proper amount of moisture present in the soil the green organic matter will undergo practically complete decomposition after three or four weeks' time.

2. In places where mud press is plentiful, the application of 2 to 3 tons of this per hectare will materially improve the physical property of abo-abo soil. The mud press should be spread over the land and then plowed under. With the application of mud press the colloidal materials of abo-abo soils will be increased, thus increasing the retentive and absorptive power of the soil.

3. The use of ammonium sulphate and nitrate of soda, supplemented with green manure, may prove effective in this type of soil.

4. The use of lime alone helps materially in improving the abo-abo soil conditions, but has not been as effective as when applied in combination with green manure or nitrogenous organic materials.

ILLUSTRATIONS

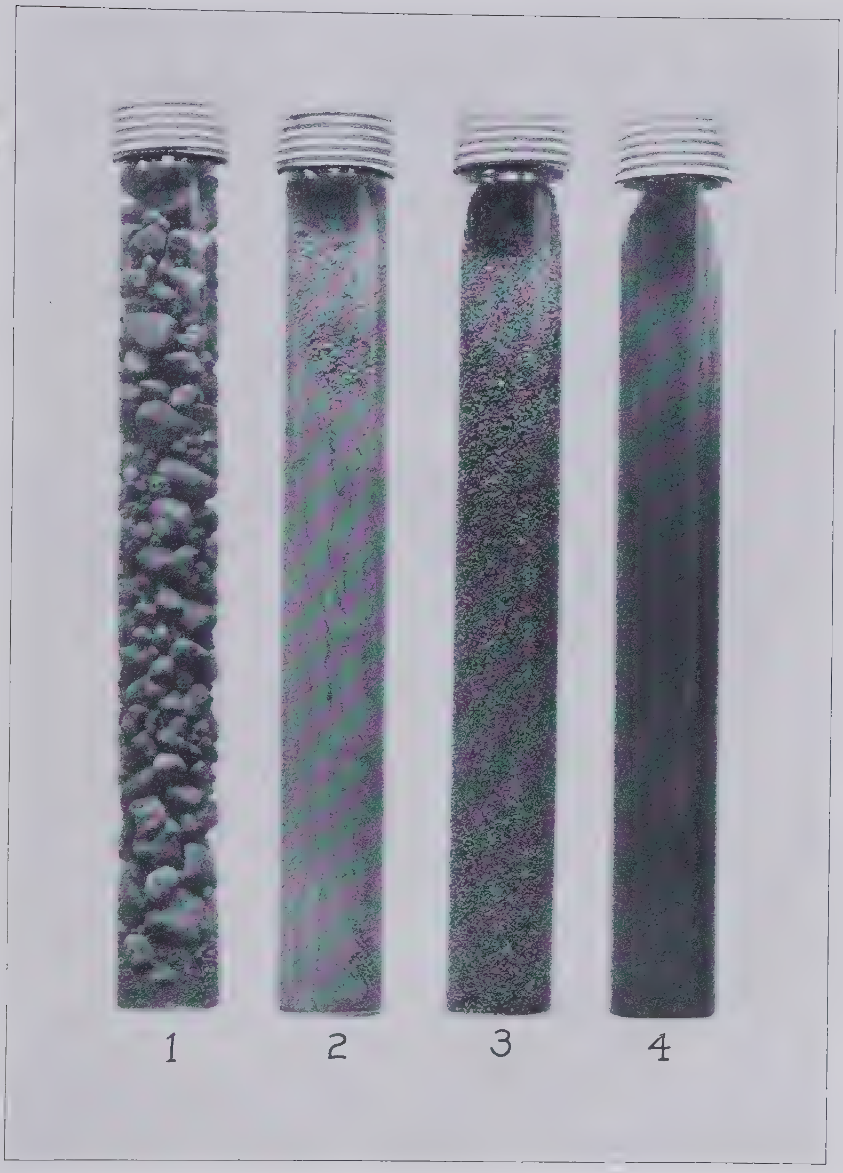

PLATE 1. THE LAYERS OF ABO-ABO SOIL.

Fig. 1. Substratum, gravel; 2, subsoil, sand, 25 to 35 centimeters deep; 3, coarse material mixed with surface soil; 4, surface soil, 15 to 25 centimeters deep.

CHAULMOOGRYL DERIVATIVES OF LACTATES AND SALICYLATES

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and

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Various derivatives of chaulmoogric acid, such as esters and anilides, have been made from chaulmoogra oil. In the present investigation a few double esters containing the chaulmoogra radical were prepared. The method of preparation consisted in treating the esters of lactic and salicylic acids with the acid chloride of chaulmoogric acid. The compounds thus obtained were chaulmoogryl derivatives of lactates and salicylates. Our results seem to indicate that these substances can be prepared rather easily, but they have a tendency to decompose in hot summer weather unless they are kept in a cool place. The new compounds prepared in this research will be tested for their therapeutic value.

EXPERIMENTAL PROCEDURE

The chaulmoogra oil used in this investigation was prepared from the seeds of the Philippine variety of chaulmoogra known as *Hydnocarpus alcalae* C. de Candolle. Dr. H. I. Cole, of the Philippine Bureau of Health, very kindly shipped a supply of the oil to us from the Culion Leper Colony.

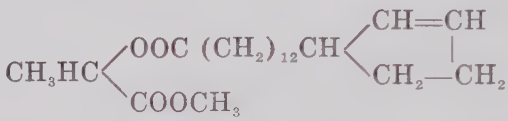
The chaulmoogric acid and acid chloride of chaulmoogric acid were prepared according to the procedure used by Santiago and West [1] in a recent investigation of chaulmoogra anilides. Chaulmoogra oil (600 grams) was saponified with alcoholic potassium hydroxide (200 grams dissolved in 80 cubic centimeters of water and 800 cubic centimeters of aldehyde-free alcohol). The mixture was heated (reflux) on a water bath for about four hours, after which the excess alcohol was removed by distillation.

[1] Philip. Journn. Sci. 33 (1927) 265.

The residual soaps were decomposed with dilute sulphuric acid (1 : 4) and the free acids extracted with ether. The ether extract was dehydrated with anhydrous sodium sulphate, after which the solution was distilled to eliminate the ether. The residue was treated with gasoline, and the precipitated resins were separated from the acid by filtering. The gasoline was then removed by distillation and the residue crystallized several times from alcohol (95 per cent). The melting point was 68° C.

The acid chloride of chaulmoogric acid was prepared by treating melted chaulmoogric acid (20 grams) with phosphorus trichloride (2.2 cubic centimeters). The reaction was finished in about fifteen minutes. The reaction product was filtered through glass wool to remove the viscous phosphorous acid, and the clear filtrate consisting of the acid chloride of chaulmoogric acid (about 18 grams) was allowed to drop slowly into an ester of lactic or salicylic acid.

CHAULMOOGRYL METHYL LACTATE



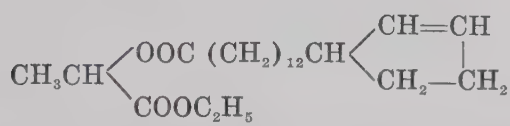
Methyl lactate (3.8 cubic centimeters) was treated with the acid chloride of chaulmoogric acid (about 18 grams) prepared as previously described. The mixture was heated (reflux) in a Crisco bath at a temperature of about 120 to 140° C. until there was no further evolution of hydrogen chloride gas. During the heating a tube containing calcium chloride was placed in the top of the condenser to prevent the access of atmospheric moisture. It required about four days to complete the reaction. The reaction product, when cooled, changed to a black solid mass. This was then crystallized from methyl alcohol to which bone black was added to decolorize the solution. About 5 grams of anhydrous sodium sulphate were also added to the solution to remove small quantities of colloidal matter which appeared to be present. The product was then crystallized twice from methyl alcohol containing bone black. The excess alcohol was evaporated and removed by exposing the solution to the breeze of an electric fan. The crystals obtained from the concentrated solution gave a melting point of from 51 to 54° C. The yield

was 10 grams, which was equivalent to about 38 per cent of the theoretical yield.

Analysis:

	Carbon. Per cent.	Hydrogen. Per cent.
Calculated for $C_{22}H_{38}O_4$	72.13	10.38
Found	71.39	9.61

CHAULMOOGRYL ETHYL LACTATE

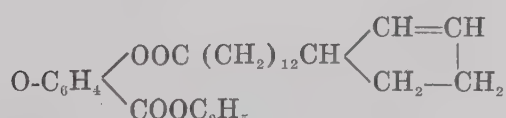


Ethyl lactate (4.5 cubic centimeters) was treated with the acid chloride of chaulmoogric acid (about 18 grams) as in the previous experiment. The mixture was heated (reflux) in a Crisco bath at a temperature of 140 to 160° C. until there was no further evolution of hydrogen chloride gas. The time required to complete the reaction was about four days. The black reaction product was crystallized once from methyl alcohol containing bone black and anhydrous sodium sulphate and several times from methyl alcohol containing only bone black. When the solution was concentrated by evaporation, the crystals obtained gave a melting point of from 54 to 57° C. The yield was 9 grams, which was equivalent to about 33 per cent of the theoretical yield.

Analysis:

	Carbon. Per cent.	Hydrogen. Per cent.
Calculated for $C_{23}H_{40}O_4$	72.63	10.53
Found	73.39	10.40

CHAULMOOGRYL ETHYL SALICYLATE



As we did not have any ethyl salicylate in our stock room we prepared this compound by dissolving salicylic acid (30 grams) in absolute alcohol (100 cubic centimeters) and adding 8 cubic centimeters of concentrated sulphuric acid to the solution. The mixture was heated (reflux) on a water bath for about two hours, after which the excess alcohol was removed

by distillation. The reaction product was then poured into about 150 cubic centimeters of water and neutralized with sodium carbonate solution. The ester was then extracted with ether and the ether extract dehydrated with anhydrous sodium sulphate. After filtering out the dehydrating agent, the ether was removed by distillation. The ester was then distilled and the fraction boiling between 220 and 227° C. was collected.

Chaulmoogryl ethyl salicylate was made by treating ethyl salicylate (6 cubic centimeters), prepared as previously described, with the acid chloride of chaulmoogric acid (about 18 grams). The mixture was heated (reflux) in a Crisco bath at a temperature of about 160 to 180° C. The reaction product when purified consisted of crystals which melted at 48 to 51° C. The yield was 5 grams, which was equivalent to about 16 per cent of the theoretical yield.

Analysis:

	Carbon. Per cent.	Hydrogen. Per cent.
Calculated for $C_{27}H_{40}O_4$	75.70	9.35
Found	74.98	9.32

CHAULMOOGRYL N-BUTYL SALICYLATE

$$O\text{-}C_6H_4\left\langle\begin{array}{l}OOC\ (CH_2)_{12}CH\left\langle\begin{array}{l}CH{=}CH\\ \quad\ |\\ CH_2{-}CH_2\end{array}\right.\\ COOCH_2CH_2CH_2CH_3\end{array}\right.$$

In the preparation of this compound, the normal butyl ester of salicylic acid was made first, after which this substance was treated with the acid chloride of chaulmoogric acid. The normal butyl ester of salicylic acid was made in the following manner: Salicylic acid (45 grams) was dissolved in absolute normal butyl alcohol (150 cubic centimeters) and the solution was treated with 12 cubic centimeters of concentrated sulphuric acid. The mixture was heated (reflux) and allowed to boil gently for about two hours. The reaction product was then treated with a concentrated solution of calcium chloride until all the excess butyl alcohol was precipitated. The mixture was then extracted with ether and the excess acid was neutralized with sodium carbonate solution. The ether extract was dehydrated with anhydrous sodium sulphate and the ether removed by distillation. The ester was distilled in vacuum (about 10 millimeters pressure) and the fraction boiling between 136 and 138° C. was collected.

Chaulmoogryl *n*-butyl salicylate was prepared by treating 4 cubic centimeters of the freshly prepared *n*-butyl salicylate with the acid chloride of chaulmoogric acid (about 18 grams). The method of preparation was about the same as that used for preparing the other double esters. The mixture was heated (reflux) in a Crisco bath at a temperature of about 180 to 190° C. for five days. The reaction product when purified consisted of crystals which melted at from 49 to 50° C. The yield was 9 grams, which was equivalent to about 27 per cent of the theoretical yield.

Analysis:

	Carbon. Per cent.	Hydrogen. Per cent.
Calculated for $C_{29}H_{44}O_4$	76.32	9.65
Found	75.71	9.66

In addition to the chaulmoogryl lactates and salicylates recorded in this paper, four other chaulmoogryl salicylates were prepared. They were the chaulmoogryl methyl, phenyl, amyl, and isoamyl salicylates. The method of preparation was similar to that employed in making the chaulmoogryl butyl and ethyl salicylates. Unfortunately, these substances were made during the hot season and, shortly after they were purified, they began to decompose slowly and acquire a slightly rancid odor. When these substances were analyzed to check the formulas, the percentage of carbon and hydrogen found was about 3 per cent lower than the theoretical percentage of these constituents. Since these impure compounds gave unsatisfactory analyses, the results are not included in this paper.

SUMMARY

Two chaulmoogryl lactates and two chaulmoogryl salicylates were prepared in this investigation; namely, chaulmoogryl methyl lactate, chaulmoogryl ethyl lactate, chaulmoogryl ethyl salicylate, and chaulmoogryl *n*-butyl salicylate.

Chaulmoogryl methyl lactate was made by treating methyl lactate with the acid chloride of chaulmoogric acid. Chaulmoogryl ethyl lactate was obtained in a similar manner by the interaction of ethyl lactate and the acid chloride of chaulmoogric acid. By treating ethyl and *n*-butyl salicylates with the acid chloride of chaulmoogric acid chaulmoogryl ethyl salicylate and chaulmoogryl *n*-butyl salicylate were obtained.

Our results indicate that these double esters can be prepared rather easily, but they have a tendency to decompose in hot summer weather unless they are kept in a cool place.

A PHYTOPHTHORA DISEASE OF SANTOL SEEDLINGS

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FOUR PLATES AND FOUR TEXT FIGURES

In August, 1924, a serious disease of santol seedling, *Sandoricum koetjape* Burm. f. (*S. indicum* Cav.), was noted in seed beds at the Singalong Experiment Station of the Bureau of Agriculture, Manila, P. I. The disease is caused by a species of *Phytophthora* hitherto not reported on this host and, as far as known, occurs only at that place. It is outwardly manifested by blights on the different parts of the young seedlings, which finally collapse and decay. The same trouble recurred the following year with so much virulence that it attracted much attention.

ECONOMIC IMPORTANCE OF THE DISEASE

The extent of damage to the santol seedlings has now been observed at the Singalong station for two successive years. Actual counts made in a seed bed 1.35 by 1.5 meters showed that 90 per cent of the seedlings were either dead or dying. In another, much larger seed bed, 1.35 by 6.2 meters, all of the seedlings showed the disease, the majority of them being dead and the remainder spindling. The two varieties of sweet santol, locally known as *bulakan* and *lamao,* were both badly infected.

In a neighboring seed bed of Para rubber plants, *Hevea braziliensis* (HBK.) Muell.-Arg., a fungus causing a similar disease was incidentally encountered and the organisms were isolated. This was later found to be produced by the fungus that causes the santol disease.

SYMPTOMS OF THE DISEASE

The disease manifests itself at a distance as a leaf blight followed by collapse of the plant. Close examination shows depressed lesions on the petioles, stem, and cotyledons (Plate 1). In badly diseased seed beds frequently only the stumps of

the seedlings remain. The first point of attack, which can be readily recognized by the typical lesions, may occur on any part of the plant above the ground.

On the leaf.—The first visible symptoms of the disease when starting on the leaves are small brown specks varying from circular to irregular in shape. Any part of the leaf may be attacked, but the leaf veins, midrib, and petiole seem to be the parts more easily affected. As the spots enlarge they become more or less greenish brown and dry up like parchment. A great part of the leaf area may thus become brown, and in some cases the entire leaf may curl up. The drying of the diseased portions takes place during sunny days following heavy rains. Under very moist conditions, as when inoculated plants are placed under bell jars, a kind of wet decay may develop rather than a blight, and defoliation may also be more rapid. Regardless of the point of origin on the leaf, the disease progresses more rapidly toward the stem, thus readily involving the tender shoots. In case the first infections occur on the petioles, the leaves fall off as soon as the disease has invaded the point of their attachment to the stem, although overlapping leaves in crowded plantings are frequently found fastened together by fungus hyphæ.

On the stem.—Lesions on the stem appear as elongated greenish brown depressions, commonly found below and above the cotyledons. These may cause a conspicuous general wilting of the leaves occasioned by interference with the water supply.

On the cotyledons.—These parts, from which the young plants obtain their food supply before the appearance of the leaves, remain firmly attached for a considerable length of time and are very readily attacked by the fungus. In fact, many of the cotyledons were found diseased, the aërial growth of the fungus on them being very evident (Plate 2, fig. 1). As they shrivel the disease invades the stem.

CONDITIONS FAVORING DEVELOPMENT OF THE DISEASE

The disease has been repeatedly observed during rainy days followed by warm weather, the conditions during the month of August being very favorable to its rapid development. At this time of the year the weather is warm and moist. Crowded planting increases the severity of the infection. Plants grown in poorly drained plots under the shade of bamboo slats were seriously damaged.

DISSEMINATION OF THE FUNGUS

The repeated occurrence of the disease in the seed beds, but never in the seed flats placed on benches about a meter above the ground and protected with a roof, indicates that rain has an important bearing upon the spread of the fungus, since the spores may be readily carried in the dropping water or may be splashed up on the plants from the soil. Cultivation and other operations in the seed beds will also spread the disease if no precautions be taken, while close planting facilitates the contamination of the neighboring plants. Under such conditions leaves overlap and come in contact, thus offering easy passage for the fungus from one leaf to another. This is readily evidenced by the frequent binding together of diseased leaves by the fungus mycelia. Insects may also act as carriers of the disease, and the use of seedlings obtained from infected seeds may likewise spread the disease to other places.

ISOLATION OF THE CAUSAL ORGANISM

A species of *Phytophthora* and a number of other fungi were isolated from the diseased areas, but inoculations have shown that only the *Phytophthora* is capable of reproducing the disease. The isolations were made by cutting out with a flamed scalpel portions of young lesions occurring on shoots, stems, and cotyledons of diseased plants. After sterilizing the surface of the portions by immersing for twenty to thirty seconds in a 1:1000 mercuric chloride solution, the portions were rinsed three times in sterile water and plated on hard potato-glucose agar +1 or on corn meal. A very uniform growth of fungus such as Phycomycetes produce was obtained in almost all of the plantings, and transfers were made from there which exhibited the most uniform appearance. The growth was most luxuriant on oatmeal agar prepared according to Clinton's(1) method as modified by Rosenbaum.(2) Pure cultures were then obtained by using the plate-dilution method, only single spore growths previously located under the microscope having been selected. In this manner the *Phytophthora* was repeatedly isolated during the month of August for two successive years, 1924 and 1925.

PROOF OF PATHOGENICITY TO SANTOL

Santol seedlings of the bulakan and lamao varieties were grown in pots of sterilized soil. These were used for the inoculation experiments.

On September 8, 1925, seedlings in one pot were inoculated by placing bits of fungus hyphæ on the young shoots and some on the leaves and cotyledons. Bits of agar containing the fungus mycelium were also used on some of the plants. These inoculated plants were kept under a bell jar for three days. Check plants were also set out under the same conditions. On September 11, three days after the inoculation, infection was very evident in all of the inoculated plants. Characteristic brown lesions on the shoots (Plate 3, fig. 2), petioles, and cotyledons were very clearly shown, particulary on the cotyledons, where the fluffy aërial growth of the fungus was conspicuous (Plate 3, fig. 1). Quicker infection was obtained where hyphæ in bits of agar were employed. The controls or checks remained normal (Plate 2, fig. 3).

In one week the inoculated plants had very few leaves left and most of them were dead (Plate 2, fig. 2). After the leaves had fallen to the ground and decayed the disease progressed downward on the stem. The plants inoculated on the cotyledons succumbed more quickly, wilting as soon as the infection developed far enough on the stem. All the inoculated plants showed marked blighting nearly identical to that occurring naturally in the seed beds.

Another set, consisting of four pots of santol seedlings, was inoculated in the same manner except that the plants were kept under very moist conditions by placing vessels of water beside the pots under the bell jars. Under these conditions the disease developed much more quickly and the plants were completely defoliated in a short time. The disease here was in the nature of a wet rot rather than a typical blight.

On July 29, 1926, another lot of santol seedlings grown in large pots of sterilized soil was inoculated. The seedlings in the three pots were inoculated in the same manner as in previous years and kept under bell jars for three days. The checks were also set out under the same conditions. All of the plants were then kept under partial shade. The results were the same as those in the previous inoculations.

In all cases *Phytophthora* was reisolated from the inoculated plants, while the controls remained normal.

INOCULATION OF OTHER SPECIES OF PLANTS WITH THE SANTOL PHYTOPHTHORA

Several species of the genus *Phytophthora* are known to attack a large number of hosts. In order to see if this is true

with respect to the santol *Phytophthora*, seedlings of various plants grown in sterilized soil in pots were inoculated with the fungus. Checks were always kept under the same conditions as those governing the inoculated plants. Reisolation of the fungus from the infected plants was made in every case.

The seedlings were found to be susceptible in the following order:

Hevea brasiliensis (HBK.) Muell.-Arg. (Para rubber); blight on shoot.
Brassica juncea (Linn.) Coss. (pechay); slight wet rot.
Raphanus sativus Linn. (radish); slight wet rot.
Lycopersicum esculentum Mill. (tomato); very slight damping off.
Solanum melongena Linn. (eggplant); very slight damping off.
Vigna sesquipedalis Linn. (sitao); infection confined to wounds.
Phaseolus sp. (bean); infection confined to wounds.
Pisum sativum Linn. (chicharo); no infection.
Cucurbita maxima Dusch. (squash); no infection.
Momordica charantia Linn. (ampalaya); no infection.
Carica papaya Linn. (papaya); no infection.
Beta vulgaris Linn. (beet); no infection.

As shown by the results of these cross inoculations the santol *Phytophthora* does not appear to affect many species of plants.

DESCRIPTION OF THE FUNGUS

Mycelium.—On various sterilized plant tissues and agars the fungus produces both aërial mycelium and submerged mycelium, the young mycelium being granular and hyaline. Submerged mycelium is much branched or gnarled when grown on hard potato-dextrose agar +1 (Plate 4, fig. 1). Characteristic of the species of *Phytophthora* young hyphæ are cœnocytic and occasionally with streaming granular protoplasm (Plate 4, fig. 2). Aërial mycelia are straight, simple, and uniform in outline, varying from 2 to 8 μ in diameter.

Conidiophores.—The conidiophores are short, somewhat larger than the vegetative hyphæ, hyaline, and granulated when young. They bear from one to four conidia in a conidiophore and measure from 7.4 to 240.5 by 3.3 to 10 μ (Plate 4, fig. 4).

Conidia.—The conidia are small and hyaline to slightly grayish on oat agar. They may be borne either terminally or intercalarily, and are ovate or lemon-shaped, some of them with a prominent papilla (Plate 4, fig. 3). Vacuoles are frequently present. Measurements of 400 conidia from pure cultures on oat agar seven to twenty-one days old were made as recom-

mended by Rosenbaum,(2) and these conform closely to those for *Phytophthora phaesoli* Thaxter. The results are given in Table 1.

TABLE 1.—*Distribution of lengths and widths of conidia of the Phytophthora from santol into size classes having a difference of 2 microns.*

Length class (in microns).	Number of conidia.	Width class (in microns).	Number of conidia.
		9.5–11.49	5
		11.5–13.49	0
		13.5–15.49	3
		15.5–17.49	4
17.5–19.49	7	17.5–19.49	26
19.5–21.49	1	19.5–21.49	25
21.5–23.49	11	21.5–23.49	61
23.5–25.49	9	23.5–25.49	58
25.5–27.49	8	25.5–27.49	93
27.5–29.49	5	27.5–29.49	41
29.5–31.49	37	29.5–31.49	57
31.5–33.49	27	31.5–33.49	21
33.5–35.49	23	33.5–35.49	2
35.5–37.49	54	35.5–37.49	4
37.5–39.49	30		
39.5–41.49	61		
41.5–43.49	22		
43.5–45.49	51		
45.5–47.49	8		
47.5–49.49	27		
49.5–51.49	3		
51.5–53.49	10		
53.5–55.49	1		
55.5–57.49	2		
57.5–59.49	0		
59.5–61.49	0		
61.5–63.49	2		
63.5–65.49	0		
65.5–67.49	1		
	400		400

As shown in Table 1 the lengths of 400 conidia range from 17.5 to 67.49 μ, and the widths from 9.5 to 37.49 μ; however, most of the lengths fall between 21.5 and 53.49 μ, and most of the widths between 17.5 and 33.49 μ. In the case of the lengths it is interesting to note, moreover, that approximately 76 per cent fall between 29.5 and 45.5 μ, while approximately 77 per cent of the widths range between 21.5 and 31.5 μ. The greatest number in any one class fall between 39.5 and 41.49 μ in length and between 25.5 and 27.49 μ in width. The average size, based on 400 measurements, is 35.7 $\times$ 25.2 μ. Text figs. 1 and 2 are graphic representations of these measurements.

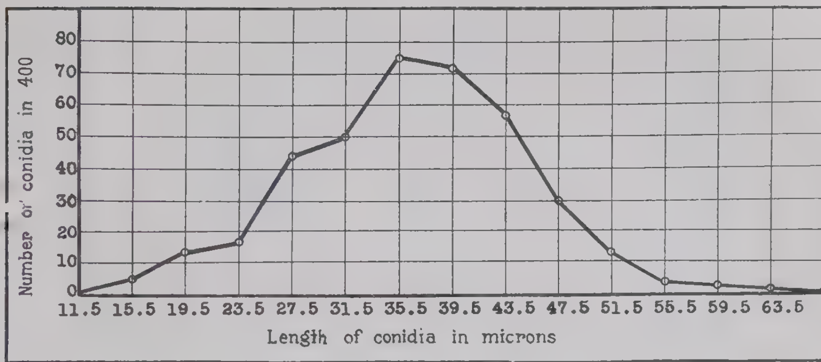

FIG. 1. Variation in the length of conidia.

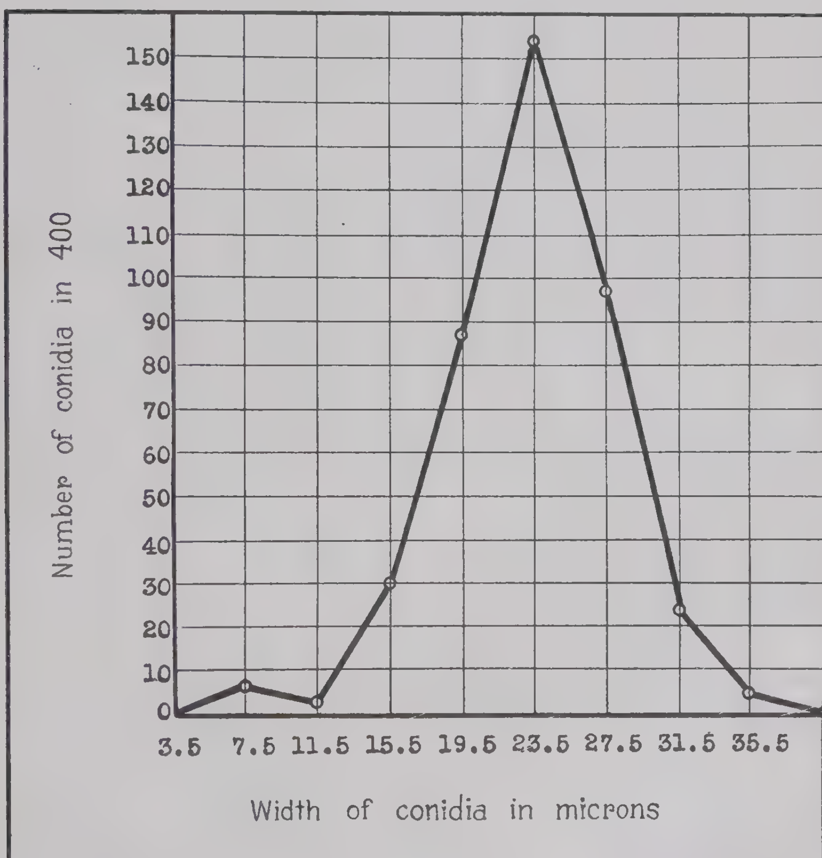

FIG. 2. Variation in the width of conidia.

TABLE 2.—*Ratio of length to width of 400 conidia arranged in classes having a range of 0.09 micron.*

Ratio class.	Conidia.	Ratio class.	Conidia.
1.05–1.14	7	1.95–2.04	7
1.15–1.24	37	2.05–2.14	0
1.25–1.34	65	2.15–2.24	5
1.35–1.44	68	2.25–2.34	3
1.45–1.54	61	2.35–2.44	2
1.55–1.64	56	2.45–2.54	2
1.65–1.74	52		
1.75–1.84	22	Total	400
1.85–1.94	12		

It will be seen in Table 2 that the ratios of length to width of 400 conidia fall between 1.05 and 2.54; most of them, however, fall between the ratios of 1.15 and 1.94, while the greatest number in any one class have a ratio of length to width falling between 1.35 and 1.44. The mean ratio of the santol *Phytophthora* is 1.51, while that of *Phytophthora phaseoli*, according to Rosenbaum,(2) is less than 1.75. A graphic representation of the ratios of length to width of the 400 conidia of the santol *Phytophthora* is given in fig. 3.

Oöspores.—The abundant production of oöspores on oat agar accords well in this respect with the behavior of *Phytophthora phaseoli*. Oöspores were obtained as early as the seventh day on oat agar and were very abundantly produced in ten- to fourteen-day cultures under room conditions at temperatures of 28 to 30° C. They were also produced abundantly on santol agar. When cultures were placed in an ice box with a temperature ranging from 25 to 28° C. the production of these reproductive organs was much earlier than this and more abundant, being formed in two to five days on oat agar.

The color of the oöspores varies from colorless to light brown or bright yellowish brown. The majority are spherical, although some are somewhat ovoid. They are borne in the oögonia and occasionally have one or two vacuoles. The oöspore walls are thick and smooth.

TABLE 3.—*Distribution of oöspores of the santol Phytophthora into diameter classes having a difference of 2 microns.*

Diameter class (in microns).	Oöspores.	Diameter class (in microns).	Oöspores.
9.5–11.49	1	23.5–25.49	91
11.5–13.49	0	25.5–27.49	125
13.5–15.49	4	27.5–29.49	4
15.5–17.49	10	29.5–31.49	2
17.5–19.49	19		
19.5–21.49	27	Total	400
21.5–23.49	117		

Measurements of 400 oöspores showed that their diameters fall between 9.5 and 31.49 μ, as shown in Table 3, although most of them range between 15.5 and 27.49 μ. Most of them have diameters in the class 25.5 to 27.49 μ. Rosenbaum (2) obtained the greatest number of oöspores for *Phytophthora phaseoli* in the

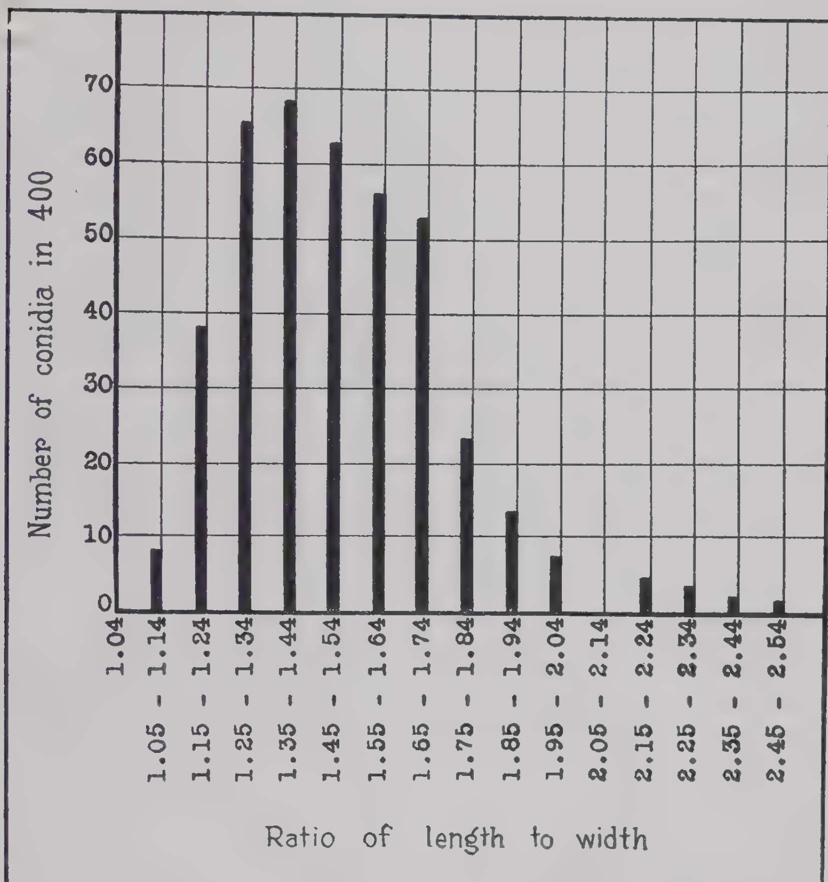

FIG. 3. Digrammatic arrangement of the ratio classes.

same class, but his range of classes is slightly less. The average diameter is 23.4 μ. A graphic representation of the above measurements is given in fig. 4.

Oögonia and antheridia.—The oögonia are for the most part terminally produced on the branches of hyphæ. The antheridia are prominent and always envelop the base of the oögonial stalk (Plate 4, fig. 5).

GERMINATION OF SPORES

Conidia.—The conidia germinate either by direct production of a germ tube at the base or through the papilla (Plate 4, fig. 6) and by the production of zoöspores (Plate 4, figs. 8 and 9).

The procedure followed in these studies was that employed by Rosenbaum.(2) Cultures of the fungus were made on oat agar in 200-cubic-centimeter Erlenmeyer flasks. At the age of the culture when conidia are known to be present abundantly which in this case is fourteen to thirty days at 28 to 30° C. and ten days at temperatures of 25 to 28° C., sterile water was carefully poured into the flasks, precautions having been taken to minimize all possible sources of contamination. The culture was then shaken to detach some of the conidia and the resulting spore suspension poured into another sterile flask. The conidia thus obtained were kept at a temperature of 14 to 20° C. by using ice. At the end of four to eight hours zoöspores were produced at these temperatures, while at room temperature they were readily produced in distilled water over night. They pass out through a break in the wall of the conidium, which occurs either at the papilla or at the side (Plate 4, fig. 7). When they are all out nothing but an empty cell remains with no sign of a break. The zoöspores while moving are irregular in shape, but when at rest are almost spherical and measure 4 to 9.3 μ. The greatest number of zoöspores observed in a conidium was 14.

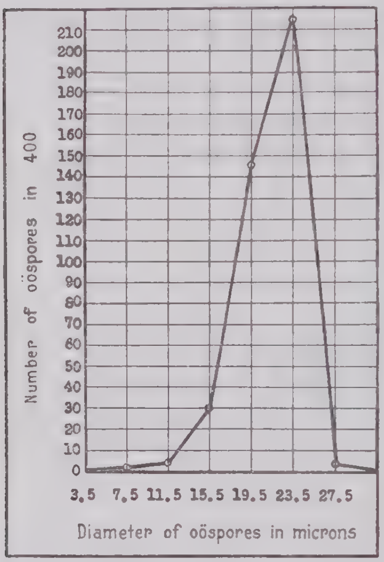

FIG. 4. Variation in the size of oöspores.

SPORE PRODUCTION AND CULTURAL CHARACTERISTICS ON VARIOUS MEDIA AND STERILIZED PLANT TISSUES

Various sterilized plant tissues and media were used in the study of spore production and growth characteristics of the fungus, observations having been made on cultures ranging in age from one to three weeks. The agars used were potato-

glucose agar, oatmeal agar, and santol-seed agar. The santol-seed agar was prepared according to the following procedure:

Santol seeds, grams	15.32
Grape sugar, gram	1.00
Agar agar, shredded, grams	3.00
Water, cubic centimeters	300

The santol seeds were cleaned and the seed coats removed before weighing. Then they were sliced with a scalpel and ground in a porcelain mortar. After grinding, 3 grams of agar were added and the mixture was placed in a beaker containing 300 cubic centimeters of water. One gram of grape sugar was added after boiling for about five minutes. The solution was then restored to 300 cubic centimeters, filtered through sterilized absorbent cotton, and tubed. It was finally sterilized in an autoclave at 15 pounds pressure for thirty minutes and slanted.

Growth on oatmeal agar.—Abundant aërial growth and abundant oöspores and conidia were produced readily.

Growth on potato-glucose agar +1.—The growth on potato-glucose agar was moderately aërial and the mycelia, particularly the submerged hyphæ, were very much branched and gnarled. Production of a few conidia and oöspores was noted occasionally on four-month-old cultures.

Growth on santol-seed agar.—Santol seed agar gave a fair aërial growth, though it was rather slow, and produced abundant oöspores and conidia. On three-month-old cultures conidia and oöspores were still in a turgid condition. The oöspores in particular were very numerous and were easily seen, owing to their deep yellowish brown color. This is a very suitable medium for the study of the reproductive organs and the mycelium, since these show up very clearly in it.

Growth on steamed rice and plain corn meal.—On steamed rice and corn meal the growth was markedly aërial and on oatmeal very profuse and fluffy, but very few spores were produced.

Growth on liquid media.—On M/100 solution of potassium carbonate prepared according to the formula of Leonian(3) transfers of mycelium made from cultures on potato-glucose agar produced sporangia in three days at temperatures of 25 to 28° C. At room temperature, 28 to 30° C., few sporangia were produced even after eight days.

On various sterilized plant tissues exceptionally abundant conidia and a few oöspores were produced on pineapple-fruit cylinders; the growth was somewhat slimy and submerged. The conidia, however, were not typical of the genus *Phytophthora.*

Most of them were much elongated, pointed, or spear-shaped. On mango-fruit cylinders abundant conidia of the same shape were obtained. On papaya cylinders a few spores also of this shape were produced. Table 4 presents all of the results on spore production.

TABLE 4.—*Production of spores of the santol Phytophthora on various media and sterilized plant tissues.*

Medium.	Spores produced after—		
	One week.	Two weeks.	Three weeks.
Potato-glucose agar + 1.	Very few conidia; no oöspores or chlamydospores.	A few conidia; no other spores.	Abundant conidia; no oöspores or chlamydospores.
Rice (steamed)	A few conidia; no oöspores or chlamydospores.	A few conidia and oöspores.	None.
Corn meal	None	A few conidia	Do.
Oatmeal	A few conidia; abundant oöspores, oögonia, and antheridia.	A few conidia; abundant oöspores.	Abundant oöspores; no conidia.
Sugar-cane cylinder	Abundant conidia; no oöspores.	Abundant conidia	Abundant conidia; a few oöspores.
Banana cylinder	None	None	None.
Pineapple fruit cylinder.	Abundant conidia only	Abundant conidia; no other spores.	Abundant conidia; a few oöspores.
Oatmeal agar	Abundant conidia and oöspores.	Abundant oöspores; a few conidia.	Abundant oöspores; a few conidia.
Bean seeds (steamed)	None	None	None.
Santol-seed agar	Abundant oögonia and antheridia; few oöspores and conidia.	Abundant oöspores and conidia.	Abundant oöspores; a few conidia.
Santol seeds	Very few conidia; no other spores.	A few oöspores; no other spores.	Abundant oöspores; no conidia.
Papaya cylinders	A few conidia and oöspores.	Very few oöspores; no other spores.	Very few oöspores; no other spores.
Potato cylinders	None	None	None.

TAXONOMY

The morphological method of Rosenbaum(2) and the physiological key of Leonian(3) for the indentification of *Phytophthora* species were followed in the taxonomic study of the santol *Phytophthora*. The conidia are larger than those of *Phytophthora phaseoli* Thaxter described by Rosenbaum,(2) but the mean ratios of length to width are in close agreement. The abundant oöspores with basal antheridia which were easily obtained in

all oat-agar cultures were also very similar in size to those recorded by Rosenbaum for *P. phaseoli.* On an average, the santol *Phytophthora* has oöspores slightly greater in diameter than those of *P. phaseoli.* These differences, however, do not seem of specific significance, in view of the variability within *Phytophthora* species. The santol *Phytophthora* is therefore referred to *Phytophthora phaseoli* Thaxter.

Leonian in his extensive physiological studies of the genus *Phytophthora* proposed to make *P. phaseoli* Thaxter a variety of *P. infestans.* The culture of *Phytophthora phaseoli* used by Leonian(3) was isolated from navy beans at Morgantown, West Virginia, but a comparison of the physiological behavior of that species with that of the santol seedlings shows many essential points of agreement. Leonian's *P. phaseoli* produced an unusual abundance of oögonia on oat agar and conidia or sporangia on M/100 solution of potassium carbonate. The Philippine santol *Phytophthora* has shown the same characteristics on these media. Leonian states, however, that the resemblance between *P. infestans* and *P. phaseoli* is too striking to be overlooked and that there is no doubt that the two belong to the same species. For this reason he places *P. phaseoli* as a variety of *P. infestans.*

CONTROL MEASURES

Infected santol seedlings in the seed beds at the Singalong Experiment Station showed a very marked improvement after having been sprayed with lime-sulphur solution (1 part of lime sulphur stock solution to 40 parts water), although it was believed from previous experience that they would be a total loss on account of the severity of the infection. After five weekly applications of the spray very little sign of the disease could be detected and some of the seedlings had developed new shoots and branches. Therefore spraying with Bordeaux mixture or lime sulphur at weekly intervals during rainy weather, and at longer intervals during the drier season, is to be recommended. Spraying the plants as soon as they begin to sprout may prove to be a good preventive measure. To make the treatment more effective, however, all badly infected seedlings should be pulled up and destroyed before application of the spray, and other plants that may serve as hosts of the disease should not be planted in close proximity to santol.

Planting seeds in sterilized soil in seed flats placed on benches about a meter high from the ground is a very certain method of control. If seed beds are used the soil should be sterilized or disinfected before the seeds are sown. Close planting should be avoided as it favors the development and spread of the fungus. In watering the seedlings care should be taken not to create a very moist condition for a great length of time. The seed beds should also be high enough above the ground to prevent contamination by surface water coming from neighboring plots.

In the Philippines the disease has not been known anywhere except at the Singalong Experiment Station. It is therefore advisable, in the light of our present information, to use all means to prevent its spread to other nurseries and places. This may be accomplished by stamping out the disease as fast as it is discovered and preventing the sale or distribution of seedlings from infected seed flats and seed beds.

SUMMARY

1. A blight disease of santol seedlings caused by *Phytophthora phaseoli*, heretofore unreported, was first found in August, 1924, at the Singalong Experiment Station of the Bureau of Agriculture, Manila, P. I.

2. The fungus causes a serious disease of the seedlings in seed beds, killing up to 90 per cent of the young plants when conditions are favorable for its development.

3. The desease produces a blight of the leaves, young shoots, stems, and cotyledons of the seedlings, resulting in the final collapse and decay of the plants.

4. It is severe during warm wet weather, but not during the drier periods.

5. The morphological and physiological characteristics of the fungus agree with the descriptions of *Phytophthora phaseoli* Thaxter, which Leonian refers to *Phytophthora infestans* var. *phaseoli*.

6. The disease may be prevented by planting seeds in sterilized soil; close planting may favor it.

7. Spraying with lime-sulphur or Bordeaux mixture, proper construction of seed beds, and careful sanitation should hold the disease in check.

ACKNOWLEDGMENTS

The writer desires to acknowledge his obligations to Dr. N. G. Teodoro, acting chief of the plant-pest control division, Bu-

reau of Agriculture, and to Dr. C. J. Humphrey, mycologist and plant pathologist in charge, Bureau of Science, for their valuable suggestions in carrying out this work; to Mr. Severo Capistrano, superintendent of Singalong Experiment Station, for furnishing some of the materials; to Mr. Gaudencio M. Reyes, assistant plant pathologist, coöperative plant pathology laboratory, Bureaus of Science and Agriculture, for furnishing certain references; and to Mr. E. Cortes, photographer, Bureau of Science, for the photographic illustrations.

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2. ROSENBAUM, J. Studies of the genus Phytophthora. Journ. Agr. Res. 8 (1917) 7, 233–276, pls. 1–7, figs. 1–13.
3. LEONIAN, LEON H. Physiological studies on the genus Phytophthora. Am. Journ. Bot. 12 (1925) 7, 444–499.

ILLUSTRATIONS

[All photographs were taken by E. Cortes.]

PLATE 1

Santol seedlings showing natural infection; removed from seed beds at the Singalong Experiment Station, Manila, P. I. About 0.5 natural size.

PLATE 2

FIG. 1. Seedlings showing typical lesions caused by natural infection on the cotyledons and stems. Natural size.

2. Seedlings artificially inoculated with the santol *Phytophthora.* About 0.25 natural size.

3. Seedlings employed as controls. About 0.25 natural size.

PLATE 3

FIG. 1. Typical infection on leaves, following artificial inoculation. About natural size.

2. Artificially inoculated seedlings showing characteristic aërial growth of *Phytophthora* on the cotyledons and adjacent parts. Slightly enlarged.

PLATE 4

[All drawings were made with the aid of a camera lucida by the author.]

FIG. 1. Gnarled growth of the mycelium of the santol *Phytophthora* on potato-glucose agar +1. × 167.

2. Typical mycelium of the *Phytophthora* showing protoplasmic granules, on oat agar. × 167.

3. Conidia showing the papilla, and some with the conidiophores, obtained from cultures on oat agar. × 167.

4. Cluster of conidia produced in hanging drop cultures. × 167.

5. Oöspores with the characteristic basal antheridia. × 167.

6. Direct germination of conidia by the production of a promycelium. × 167.

7. Conidia forming zoöspores. × 167.

FIGS. 8 and 9. Germinating zoöpores. × 167.

TEXT FIGURES

FIG. 1. Graph showing variation in the length of conidia.

2. Graph showing variation in width of conidia.

3. Diagrammatic arrangement of the ratio classes.

4. Graph showing variation in size of zoöspores.

PLATE 1.

1

2

PLATE 2.

1

2

PLATE 3.

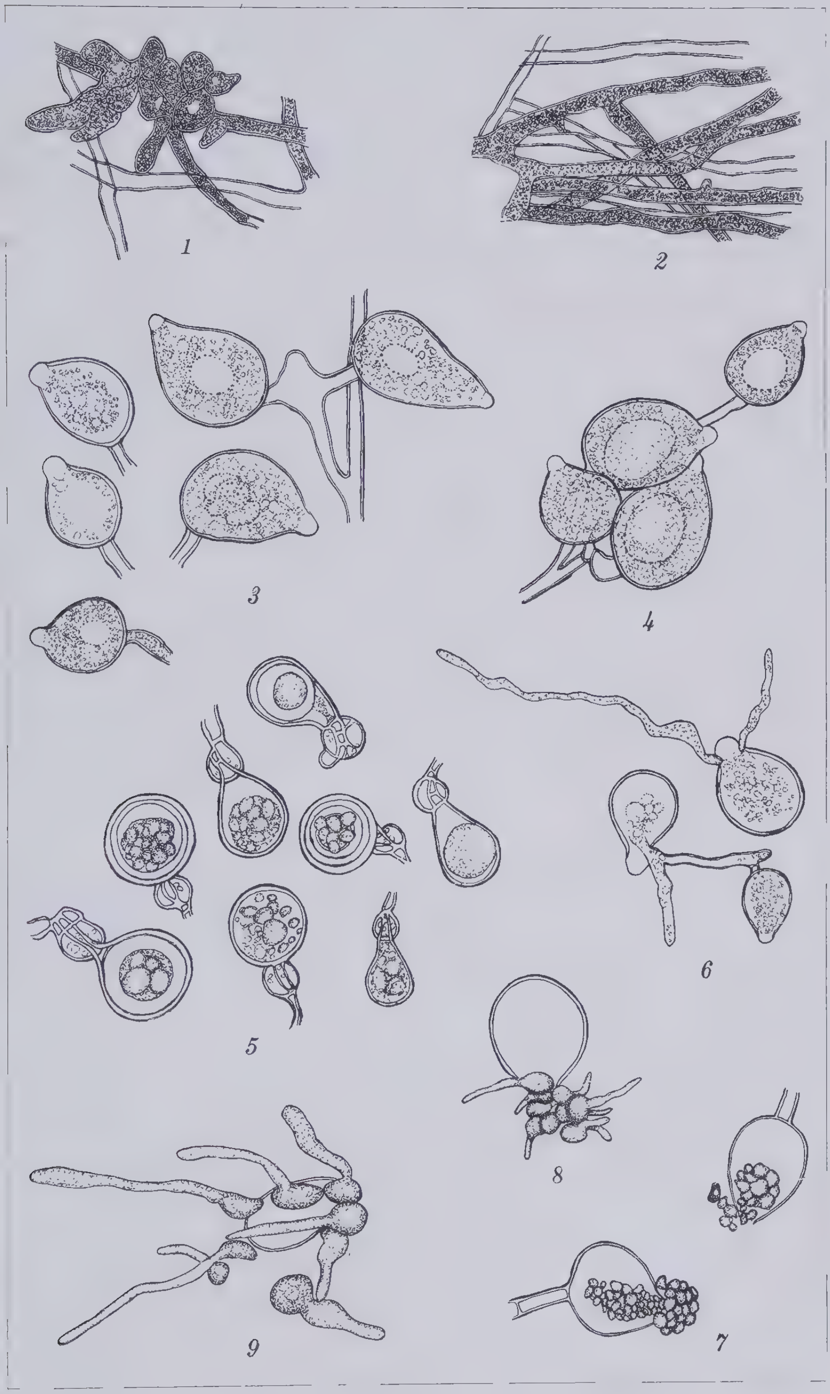

PLATE 4.

CHARLES FULLER BAKER

By E. O. Essig

Professor of Entomology, College of Agriculture, University of California Berkeley

ONE PLATE

Charles Fuller Baker, entomologist, botanist, agronomist, collector, teacher, agricultural director and dean, died at St. Luke's Hospital in Manila, Philippine Islands, on July 21, 1927, aged fifty-five years. According to word received from D. L. Crawford, "his death was due to chronic dysentery which became acute and confined him in the hospital for two weeks before the day of his death." It is a comfort to his friends to know that during his illness he was attended by one of his own students, Capt. Leon L. Gardner, of Sternberg General Hospital in Manila. He was buried on the campus of the University of the Philippines where he spent the last nine years of his arduous life. He was born at Lansing, Michigan, March 22, 1872, the second son in a family of ten children, and was the brother of the noted author, Ray Stannard Baker, and the forester, Hugh Potter Baker.

At the Michigan Agricultural College, from which he graduated in 1892, he came under the instruction of Prof. Albert John Cook, who exerted a profound influence upon his studies in entomology and botany as well as upon many of his later activities in life. Professor Cook once told me that Baker, when a student at college, spent all of his cash for insect boxes, and by the time he graduated he had several hundred boxes of specimens, a larger and more-complete collection than was at the college at that time. As an undergraduate he assisted Professor Cook in 1891 and 1892 when he was transferred as assistant to Prof. C. P. Gillette at the Colorado Agricultural College, Fort Collins, Colorado. Here he made very extensive botanical and entomological collections and began publishing. One of his first important contributions was "A

preliminary list of the Hemiptera of Colorado"[1] in co-authorship with Professor Gillette. Most of his earlier papers dealt with the Homoptera and particularly the Cicadellidæ. It was in this publication that he described the sugar-beet leaf hopper, *Eutettix tenellus*, as *Thamnotettix*.[2] In 1893 he was in charge of the Colorado forestry and zoölogical exhibit of the Columbian Exposition at Chicago. The years 1897 to 1899 were spent partly in Alabama, where he acted as zoölogist in the Alabama Polytechnic Institute and entomologist in the Agricultural Experiment Station. Here he was connected with the Alabama Biological Survey. During 1898 and 1899 he was botanist on the H. H. Smith [3] exploring expedition in the Santa Marta Mountains, Colombia. In 1899 to 1901 he was a teacher of biology in the Central High School at St. Louis, Missouri. Following this he studied with Prof. Vernon L. Kellogg at Stanford University, where he obtained the degree of Master of Science in 1903.

Through the efforts of Professor Cook, Baker was induced to accept the position of assistant professor of biology at Pomona College in 1903, but he remained there only one year. During this year he began the publication of Invertebrata Pacifica.[4]

He left California to become chief of the department of botany of the Cuban Experiment Station (Estación Agronómica), Santiago de las Vegas, Cuba, which position he held from 1904 until 1907. During this busy period also he published two very important papers on the then little-known fleas of North America.[5]

[1] Colorado Agr. Exp. Sta., Fort Collins, Colo. Bull. No. 31, Tech. Ser. No. 1 (1895) 137.

[2] The generic position of this insect is still questioned by systematists.

[3] Celebrated entomological explorer and collector.

[4] This serial appeared as follows: Homoptera, Vol. 1, pp. 1–12, Sept. 15, 1903; Orthoptera, pp. 13–16, Nov. 30, 1903; Diptera, pp. 17–40, Feb. 10, 1904; Hymenoptera, pp. 41–70, Aug. 26, 1904; Orthoptera, pp. 71–84, Jan. 30, 1905; Neuropteroid Insects, pp. 85–92, May 15, 1905; Hymenoptera, pp. 93–110, Aug. 20, 1905; pp. 111–132, Oct. 27, 1905; Heteroptera, pp. 133–140, Jan. 24, 1906; Hymenoptera, pp. 141–159, May 24, 1906; pp. 161–178, Feb. 28, 1907; pp. 179–198, Oct. 8, 1907. It was begun at Claremont, California, and completed (pp. 71–198) during his stay at Santiago de las Vegas, Cuba. It contained descriptions of insects which he collected personally, mostly in California and Nevada. A part of his insect collection containing types and paratypes of many of these is at Pomona College along with many exotics collected in Cuba and Brazil.

[5] Rev. Am. Siphonaptera, Proc. U. S. Nat. Mus. **27** (1904) 1–365. Classification of N. A. Siphonaptera, ibid. **29** (1906) 1–121.

From Cuba he went to Brazil to assume the position as curator of the Herbarium and Botanical Garden, Museu Goeldi at Para, where he stayed one year. In Brazil he amassed very large collections of both plants and insects which were presented to Pomona College upon his return there in 1908. It was at the beginning of my junior year in college there that I came under his singular guidance. With the enthusiasm, confidence, and untiring coöperation of Professor Cook, he accomplished a remarkable piece of work at that institution. His influence upon students was very unusual, and he stimulated the most backward to produce surprising results. Many things—equipment, housing facilities, money—were needed to supply him. These were secured by Professor Cook, either directly from the college or from private individuals. Entomology at once forged ahead of all other biological sciences. Systematic and life-history work became fundamental. For the citrus-fruit growers of the region a system of orchard inspection was organized, which gave not only excellent field experiences, but also remunerative employment for advanced students, and rich returns to the growers. During his four years' stay there he inspired, trained, and sent out a fairly large group of biologists in consideration of the small size of the institution at that time.[6]

Early in 1909 he explained to Professor Cook the great need of serial publications, not only as an outlet for the work of students and specialists, but also for the benefit of all interested in the biological sciences, especially entomology and botany. Professor Cook at once agreed and undertook, single-handed, to raise sufficient money by private subscription to finance first a Journal of Entomology[7] and then a Journal of Economic Botany.[8] The former appeared in March, 1909, and the latter

[6] Among this group were Charles W. Metz, J. E. Graf, D. L. Crawford, B. L. Boyden, C. F. Stahl, H. J. Ryan, F. R. Cole, A. R. Davis, John A. Prizer, R. S. Vaile, A. R. Baird, H. A. Weinland, Harry V. M. Hall, Gertrude Bacon (Mrs. H. L. Chaffee), Vinnie E. Stout (Mrs. B. P. Aborn), Blanch E. Stafford (Mrs. Charles W. Metz), Leon L. Gardner, and Sarah R. Atsatt.

[7] Baker edited Vol 1 (1909) through No. 2, Vol. IV (1912). When Dr. W. A. Hilton succeeded as head of the department of biology and editor of the scientific journals he changed the name to Journal of Entomology and Zoölogy, beginning with Vol. V (1913).

[8] The Journal of Economic Botany edited by Baker continued through three volumes, I (1911), II (1912), III (1913). Its discontinuance was announced in Nos. 3 and 4, Vol. III, Dec., 1914, by D. L. Crawford, then professor of botany at Pomona College.

in February, 1911. Another notable contribution was the publication of the First Annual Report of the Laguna Marine Laboratory [9] in 1912. The Pomona College marine station at Laguna Beach was organized almost entirely through the efforts of Professors Cook and Baker, with financial assistance from a few local residents, and it is still ably conducted by Doctor Hilton.

In October, 1911, the appointment of Professor Cook as horticultural commissioner of California broke the magic ring of activities at Pomona. When he removed to Sacramento there was no one left to solicit the necessary funds to continue the work which was more than could be assumed by the college. Certain restrictions were also made to prevent outside solicitations for aid which appeared to handicap permanently the future development of the important work so gloriously started. After a year of disappointment Baker finally decided to accept the position of professor of agronomy at the University of the Philippines which was offered him by his good friend Dean E. B. Copeland, whom he succeeded in 1918. During his long stay in the Philippines he left only once and that was for a year's leave of absence in 1917–1918 to become assistant director of the Botanic Gardens at Singapore. Every ounce of vitality was poured into his work. His entomological collections received the greater part of his spare time. He maintained at his own expense a Cuban collector named Julian Hernandez, whom he carefully trained and kept with him after he left Cuba in 1907. This man spent all of his time either collecting or caring for the insects, or in the domestic duties of a bachelor's household. Botany came in for a share also, and fungi in particular were collected extensively throughout the Archipelago. Every cent of his salary that could be utilized went toward building up the collections. Concerning these he writes under date of April 27, 1925:

> My outside work in entomology and mycology is the only thing that gives me any real satisfaction; that, at least, is done as it ought to be done and I can go on and develop it to the limit of personal possibilities without let or hindrance from anyone. I have pushed the number of foreign specialists engaged on our work up to one hundred ten, and keep them all busy! It thus has become one of the biggest projects of its kind

[9] Published by the Department of Biology, Pomona College, Claremont, California, 218 pp., 130 figs.

in the world. And its ultimate permanent contribution to entomology will be very, very large. And this helps very materially to make the stay here worth while.

Failing health and disappointments many times influenced him to desire to give up his position in the Philippines and seek a place of complete change and a haven of peace and quiet in America where he could find space to house and work on this large insect collection during the remaining years of his life. To this end an attempt was made to secure for him a place at the California Academy of Sciences, but the difficulty of raising a proper endowment indefinitely delayed action until it is now too late. On August 30, 1925, he wrote: "The outside work I am carrying constantly looms larger and larger and it makes me want to stay here. But poor health will probably force me to cut loose ere long."

For several years he was considering an offer from a strong combination of all the entomological interests of the Hawaiian Islands to conduct extensive work in the western Pacific Islands—"Over Wallace's Trail." His failure to negotiate terms in California and the opportunities offered by his own student, President Crawford, of the University of Hawaii, led him finally to accept the Hawaiian offer. Accordingly, he presented his resignation to the College of Agriculture, University of the Philippines, to take effect in November, 1927. In Science [10] it is stated that—

he expects to spend next year with one of the Pan-Pacific research committees on the South Sea Survey and thereafter will make headquarters at the University of Hawaii with Pres. David Crawford. Arrangements have been made to house his large collections of natural-history material at the Bishop Museum.

On June, 9, 1927, the Board of Regents of the University of the Philippines passed a resolution appointing him Professor of Tropical Agriculture and Dean Emeritus of the College of Agriculture of the University of the Philippines, and also Director Emeritus of the Experiment Station, effective December 1, 1927. His untimely death came before this much-earned public recognition was realized.

His insect collection is a remarkable achievement, amassed over a period of fourteen years of unremitting labor. From

[10] Vol. 66, No. 1699, p. 77, July 22, 1927.

reports received from Baker in 1926, it contained approximately four hundred thousand specimens. On November 9, 1926, he wrote me concerning it:

The collection is undoubtedly the largest existing private collection covering the extreme western Pacific. The pinned part of it is contained in one thousand five hundred cases, all crowded full. But as much more has been placed in the hands of one hundred ten (later one hundred fifteen) specialists [11] and considerable portions of the latter will be returned. I believe it is one of the most important collections *basic* to either Central and South Pacific work or to Southwest Asian studies since it includes several thousand types and cotypes. Moreover, more material is constantly coming in and I have so arranged it that continued collections on a large scale will be made after I leave here. I also have a lot of fine Australian material constantly coming in. Moreover, I have taken the fullest advantage of exchange possibilities, making important exchanges with European museums and with individuals, in this way securing a vast number of species I lacked, many of these being cotypes.

According to S. A. Rohwer, information received by Dr. L. O. Howard from Baker indicates that the insect—

collection is considerably larger than it was in November, 1926, as Baker received from specialists quite a little material during the winter of 1926–27 and also continued to mount miscellaneous material which had been collected. The figures for the number of cases undoubtedly referred to the pinned part only. From information and letters, I gather that there is probably half as many specimens that are unmounted.

All the mounting, labeling, packing, and shipping to specialists was done by Baker himself at night, the entire work including the salary of the collector already referred to, cost of pins, boxes, labels, packing, and postage, was supported by his modest salary; yet, as he states, "if one lives simply and rigorously as a Trappist monk, many things may be possible." According to

[11] Some of the specialists who were supplied with entomological material by Baker: COLEOPTERA, Hans Gebien, R. Kleine, and A. Zimmermann, Germany; A. Boucomont, Ed. Fleutiaux, A. Grouvelle, and M. Pic, France; Jan Obenberger, Czecoslovakia; H. Krekich-Strassoldo, Austria; Chr. Aurivillius, Sweden; H. E. Andrewes and Guy A. K. Marshall, England; Edward A. Chapin, United States. ORTHOPTERA, Achille Griffini, Italy; H. H. Karny, Dutch East Indies; A. N. Caudell, United States. HOMOPTERA, Frederick Muir and D. L. Crawford, Hawaii; L. Melichar, Moravia; W. D. Funkhouser and T. D. A. Cockerell, United States. HEMIPTERA, W. L. McAtee and J. R. Malloch, United States. DIPTERA, P. Sack, Germany; W. S. Patton, Scotland; M. Bezzi, Italy; J. R. Malloch and G. F. Ferris, United States. HYMENOPTERA, E. A. Elliott, England; H. L. Viereck, Canada; T. D. A. Cockerell, United States. Baker worked chiefly in Homoptera on the Jassoidea, Fulgoridæ, and Cercopidæ, and in the Hymenoptera on the parasitic Braconidæ, during his stay in the Philippines.

his long-standing will, the main insect collection was bequeathed to the United States National Museum. The statement that small parts were also donated to the Universities of Berlin, London, Madrid, Paris, Moscow, and Vienna,[12] is probably erroneous. Crawford states that—

he [Baker] was stricken so suddenly by this accute attack of dysentery that he had no time to make any changes in his will . . . . . and according to cable information received from Manila his old will still stands whereby the United States National Museum is to receive his main insect collection and the University of the Philippines is to receive his main collection of plant material.

Rohwer also states that—

the will provides that the entire collection, manuscripts and notes, should come to the National Museum. We have never been advised that there were any changes. The Museum is planning to make arrangements to have the collection transferred to Washington as soon as practical after the will is probated.

Entomology and mycology were only side issues or hobbies; his real work was the development of agriculture in the Philippines. A perusal of the files of the Philippine Journal of Science,[13] the Philippine Agriculturist, and the Philippine Agricultural Review, on all of which he was an editorial associate, will give some idea of the results accomplished. Concerning this broader work the following editorial of the Tribune[14] is pertinent:

The Baker Leadership! The University of the Philippines can ill afford to lose the services of Dean Charles F. Baker of the College of Agriculture. He has made of his college an institution of the highest standing in this country and one to which recognition abroad has been deservedly given. The Los Baños unit of the University [is] what it is because Dean Baker has put in its organization and management much of his own forceful personality and transferred to the faculty his own enthusiasm for its mission.

The work of bringing advanced methods of agricultural practices to the people on the farms has only been started. It is the work not for a decade but for a generation. In this task Dean Baker has been easily a recognized leader. It is not too much to say of him that, were he

[12] Science, No. 1701, 46 (August 5, 1927) 129.

[13] In this journal were published the results of much of the entomological work done by Baker and the large corps of specialists to whom he forwarded his material.

[14] Independent Filipino Daily, Carlos P. Romulo, editor, Manila, P. I. (Nov. 6, 1926) 4.

to leave the college permanently, the Baker leadership will yet be felt through years to come. It is a measure of his success that what is often good in scientific agriculture may be traced to a Baker tradition.

Baker was a member of the American Association for the Advancement of Science, American Association of Economic Entomologists, Entomological Society of America, Washington Entomological Society, Southern California Academy of Sciences, and the Havana Academy.

Although he died comparatively young, he did the life work of ten men.

ILLUSTRATION

PLATE 1. CHARLES FULLER BAKER

The portrait on the left was taken during his stay at Pomona College, Claremont, California, in 1909; that on the right when he was at the College of Agriculture, University of the Philippines, Los Baños, P. I., in 1925.

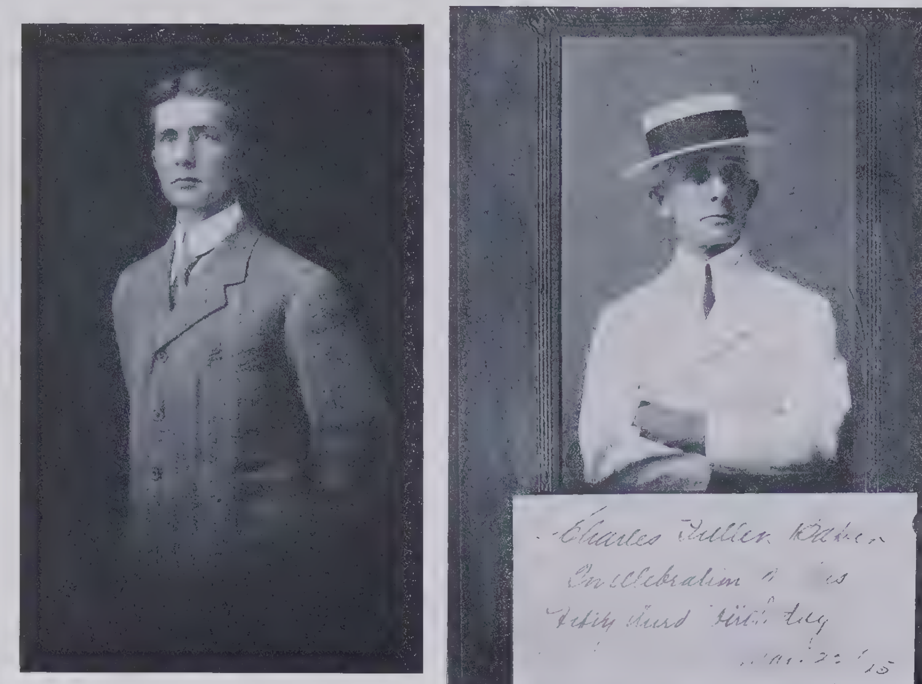

PLATE 1.

NEW STEPHANIDÆ FROM BORNEO AND THE PHILIPPINE ISLANDS, IV

By E. A. Elliott

Fellow of the Zoological Society of London and of the Entomological Society of London

Subfamily PARASTEPHANELLUS Enderlein

This subfamily is confined to the Indo-Australian Region, and is characterized by the discoidal cell being petiolate, and only about half as large as the cubital. I include in the following table the few species previously recorded from Borneo and the Philippines.

Key to species of the genus Parastephanellus.

FEMALES

1\. 18. Hind femora tridentate.

3\. 2. Terebra half as long again as body; metapleuræ smooth, hind metatarsi not white .... **P. caudatus** Elliott.

2\. 3. Terebra not much longer than body.

5\. 4. Vertex basally and laterally punctate; stigma very large. **P. crassistigma** sp. nov.

4\. 5. Vertex not punctate; stigma normal size.

7\. 6. Occiput finely transstriate, frons shagreened. **P. curticollis** Elliott.

6\. 7. Occiput smooth.

9\. 8. Frons arcuate striate, apically nearly smooth; vertex rugose, laterally smooth .... **P. rufescens** Elliott.

8\. 9. Frons not arcuate striate.

13\. 10. Frons rugose.

12\. 11. Frons irregularly, vertex finely rugose; median segment coarsely punctate .... **P. impunctatus** Elliott.

11\. 12. Frons granulate rugose, vertex transstriate; median segment superficially punctate .... **P. montanus** sp. nov.

10\. 13. Frons obliquely or transversely striate.

15\. 14. Frons obliquely striate, vertex transversely; metapleuræ smooth above, coarsely punctate beneath .... **P. monticola** Elliott.

14\. 15. Frons transversely striate.

17\. 16. Frons and vertex finely transstriate; metapleuræ and median segment coarsely punctate .... **P. similis** Elliott.

16. 17. Frons coarsely, vertex finely transstriate; metapleuræ rugose, median segment reticulate punctate........................ **P. politus** sp. nov.
1. 18. Hind femora bidentate.
28. 19. Terebra only as long as body.
21. 20. Neck longitudinally striate................................ **P. rubripictus** Elliott.
20. 21. Neck not longitudinally striate.
25. 22. Frons more or less arcuate striate.
24. 23. Frons coarsely arcuate striate, ocellar space pentagonal, petiole shorter than rest of abdomen........................ **P. rugipleurae** sp. nov.
23. 24. Frons only basally arcuate striate, ocellar space normal; petiole longer than rest of abdomen........................ **P. variegatus** sp. nov.
22. 25. Frons not arcuate striate.
27. 26. Frons granulate; hind femora with two conspicuous blunt teeth behind the long sharp ones............................ **P. quadridens** sp. nov.
26. 27. Frons coarsely rugose; hind femora without conspicuous smaller teeth.. **P. crassicoxae** sp. nov.
19. 28. Terebra longer than body.
34. 29. Terebra at least half as long again as body.
31. 30. Hind femora strongly incrassate; frons subgranulate rugose, occiput apically transtriate... **P. crassifemur** sp. nov.
30. 31. Hind femora normal.
33. 32. Frons finely and closely rugose, occiput apically transstriate; petiole longer than rest of abdomen .... **P. claripennis** Cameron.
32. 33. Frons finely and evenly, vertex indistinctly transstriate, occiput smooth; petiole as long as rest of abdomen.... **P. fulgens** sp. nov.
29. 34. Terebra much less than half as long again as body.
36. 35. Posterior margin of head simple; pronotum, pro-, meso-, and metapleuræ smooth.. **P. palliditarsis** Cameron.
35. 36. Posterior margin of head bordered.
38. 37. Frons arcuate striate, metapleuræ and median segment coriaceous, former closely, latter diffusely punctate.... **P. polychromus** Kieffer.
37. 38. Frons not arcuate striate; metapleuræ not coriaceous.
40. 39. Frons transstriate, metapleuræ punctate, median segment coriaceous .... **P. parvus** sp. nov.
39. 40. Frons subrugose striate; metapleuræ coarsely punctate, smooth apically above; median segment superficially punctate. **P. niger** sp. nov.

MALES

6. 1. Hind femora tridentate.
3. 2. Metapleuræ smooth, separated from median segment by an impression .... **P. glaberrimus** sp. nov.
2. 3. Metapleuræ sculptured.
5. 4. Metapleuræ closely punctate, separated by a crenulate sulcus. **P. politus** sp. nov.
4. 5. Metapleuræ transrugose above, otherwise coarsely punctate, separated by a carina... **P. montanus** sp. nov.
1. 6. Hind femora bidentate.
8. 7. Basal section of radius strongly bisinuate........ **P. sinuatus** sp. nov.
7. 8. Basal section of radius straight or simply curvate.
10. 9. Vertex smooth.. **P. minutus** sp. nov.

9. 10. Vertex sculptured.
14. 11. Vertex and occiput transrugose.
13. 12. Neck with one transcarina; mesopleuræ smooth.
P. maculifrons Cameron.
12. 13. Neck coarsely longitudinally striate; mesopleuræ finely punctate .... **P. rubripictus** Elliott.
11. 14. Vertex transstriate, occiput smooth.
16. 15. Posterior margin of head simple.................. **P. palliditarsis** Cameron.
15. 16. Posterior margin of head bordered.
18. 17. Frons and vertex indistinctly sculptured; hind femora inflated.
P. leviceps sp. nov.
17. 18. Frons and vertex distinctly sculptured.
20. 19. Frons granulate; hind femora with two large blunt teeth behind the long sharp ones.................... **P. quadridens** sp. nov.
19. 20. Frons not granulate; smaller teeth not conspicuous.
26. 21. Frons more or less arcuate striate.
25. 22. Frons entirely arcuate striate, vertex and occiput transstriate.
24. 23. Pronotum smooth, median segment coriaceous, closely punctate .... **P. polychromus** Kieffer.
23. 24. Pronotum and median segment coriaceous, latter only laterally punctate.................... var. **coriacea** Kieffer.
22. 25. Frons only basally arcuate striate; median segment superficially and diffusely punctate.................... **P. variegatus** sp. nov.
21. 26. Frons not arcuate striate.
28. 27. Frons transrugose, vertex coarsely transstriate; metapleuræ rugose punctate.................... **P. rugifrons** sp. nov.
27. 28. Frons and vertex finely transstriate.
30. 29. Metapleuræ smooth above, punctate beneath; median segment indistinctly sculptured, separated by a slight carina.
P. leviceps sp. nov.
P. parvus sp. nov.
29. 30. Metapleuræ coarsely punctate, with a smooth space apically above; median segment superficially punctate, separated by a strong carina.................... **P. niger** sp. nov.

PARASTEPHANELLUS CAUDATUS Elliott.

Parastephanellus caudatus ELLIOTT, Philip. Journ. Sci. 29 (1926) 521. Female.

PARASTEPHANELLUS CRASSISTIGMA sp. nov.

Female.—Frons inrregularly punctate, vertex transstriate, laterally and basally punctate; occiput smooth; posterior margin of head finely bordered; one strong carina between posterior ocelli; posterior tubercles broad. Scape scarcely as long as cheeks, antennæ normal. Pronotum short and smooth. Mesonotum smooth, with three rows of punctures. Scutellum smooth. Mesopleuræ smooth, basally finely aciculate. Metapleuræ smooth above, otherwise coarsely punctate, separated by a narrow punctate sulcus from the median segment, which

is basally diffusely punctate laterally and apically smooth. Petiole finely transstriate, shorter than the remaining smooth, shining segments. Terebra longer than body, black. Hind coxæ coarsely transstriate, as long as the femora, which are smooth above, laterally transaciculate, tridentate, the basal tooth rather small. Tibiæ compressed to beyond middle; metatarsi nearly three times as long as the remaining joints. Radius emitted from beyond middle of the very large stigma, its distal section three times as long as the proximal.

Black; head red, vertex and occiput darker, outer orbits pale, antennæ basally and median segment red; anterior legs rufescent, middle tibiæ and tarsi basally white, hind tarsi rufescent.

Length, 9 millimeters; abdomen, 5.5; petiole, 2.5; terebra, 14.

SINGAPORE (*Baker*).

The sculpture of the median segment is peculiar. It is unusual for the hind metatarsi to be entirely rufescent, when the middle ones are white basally.

PARASTEPHANELLUS CURTICOLLIS Elliott.

Parastephanellus curticollis ELLIOTT, Philip. Journ. Sci. **29** (1926) 524. Female.

PARASTEPHANELLUS RUFESCENS Elliott.

Parastephanellus rufescens ELLIOTT, Philip. Journ. Sci. **29** (1926) 523. Female.

PARASTEPHANELLUS IMPUNCTATUS Elliott.

Parastephanellus impunctatus ELLIOTT, Philip. Journ. Sci. **29** (1926) 523. Female.

PARASTEPHANELLUS MONTANUS sp. nov.

Female and male.—Frons varies from roughly transstriate to almost granulate rugose; vertex very finely transstriate; occiput smooth and shining, finely longitudinally impressed; posterior margin of head bordered; posterior tubercles small but distinct, often joined by a more or less distinct bisinuate ridge; three carinæ behind posterior ocelli. Scape about as long as cheeks; antennæ normal, third flagellar joint sometimes slightly longer than first and second together. Pronotum very short, neck laterally more or less transstriate. Mesonotum finely diffusely punctate, with three fine punctate impressions. Central lobe of scutellum smooth and shinning, separated by narrow punctate sulci from the dull, finely punctate lateral lobes. Mesopleuræ dull, finely transaciculate. Metapleuræ coarsely punctate, separated by a more or less distinct crenulate sulcus from the reticulate punctate median segment. Petiole finely transstriate,

as long as the remaining segments in female, slightly shorter in male. Terebra in female as long as body or slightly longer. Hind coxæ coarsely transstriate, as long as the tridentate femora; tibiæ much longer than femora, compressed in basal two-fifths; metatarsi more than twice as long as the remaining joints in female, little longer in male. Radius emitted from distal third of stigma, its distal section three times as long as the proximal.

Black; frons red; face, base of mandibles, cheeks, temples, and two basal antennal joints testaceous or rufotestaceous; vertex and occiput black, or latter basally paler; carinæ on vertex red; a pale line under eyes. Legs often more or less rufescent, middle tibiæ and metatarsi basally hind metatarsi entirely white. Wings hyaline, stigma and nervures red-brown to black.

Length: Female, 9.5 to 13 millimeters; abdomen, 6 to 8; petiole, 3 to 4; terebra, 10 to 14; male, 9 to 11.5 millimeters; abdomen, 5 to 7; petiole, 2.5 to 3.5.

NEGROS, Cuernos Mountains. MINDANAO, Kolambugan. BORNEO, Sandakan (*Baker*).

Closely allied to my *P. monticola,* but differs in the sculpture of the frons, mesonotum, meso-, and metapleuræ.

PARASTEPHANELLUS MONTICOLA Elliott.

Parastephanellus monticola ELLIOTT, Philip. Journ. Sci. 29 (1926) 524. Female.

PARASTEPHANELLUS SIMILIS Elliott.

Parastephanellus similis ELLIOTT, Philip. Journ. Sci. 29 (1926) 522. Female.

PARASTEPHANELLUS POLITUS sp. nov.

Female.—Frons rather coarsely transstriate, two weak carinæ behind the posterior ocelli, vertex very finely transstriate, occiput and ocellar space smooth; posterior margin of head bordered; posterior tubercles well developed. Scape as long as cheeks; antennæ normal. Apical half of neck deeply impressed and laterally finely transstriate, basal half and the semiannular smooth. Mesonotum superficially punctate, apically smooth, with three punctate impressions. Scutellum smooth centrally, with marginal punctures, lateral lobes punctate. Mesopleuræ smooth, very finely punctate beneath. Metapleuræ transrugose above, otherwise coarsely punctate, separated by a carina from the reticulate punctate median segment. Petiole finely transstriate, as long as rest of abdomen, second segment basally

rugose. Terebra longer than body, black. Hind coxæ transstriate, as long as the smooth, tridentate femora; tibiæ slightly shorter than femora and trochanters together, compressed to middle; metatarsi twice as long as the remaining joints. Radius emitted from apical third of stigma, which is rather broad, its distal section twice as long as the proximal.

Black; head red, vertex and occiput black; pronotum, base of second segment, and the hind tibiæ rufescent; anterior legs and hind tarsi rufotestaceous; middle tibiæ and metatarsi basally white; stigma and nervures red-brown. Antennæ basally testaceous.

Male.—Agrees in sculpture with the female, but the frons is more finely sculptured; hind metatarsi barely as long as rest.

Black; head and base of antennæ rufotestaceous, vertex and occiput nigrescent; pronotum, base of second segment, and hind trochanters red; anterior legs, apex of hind tibiæ, and their tarsi rufostestaceous.

Length: Female, 12 millimeters; abdomen, 8; petiole, 4; terebra, 14; male, 10 millimeters; abdomen, 6; petiole, 3.

MINDANAO, Dapitan (*Baker.*)

PARASTEPHANELLUS RUBRIPICTUS Elliott.

Parastephanellus rubripictus ELLIOT, Proc. Zool. Soc. London (1922) 759. Female and male.

PARASTEPHANELLUS RUGIPLEURAE sp. nov.

Female.—Frons coarsely arcuate striate, ocellar space pentagonal, bounded apically by carinæ between the inconspicuous anterior tubercle and the middle pair, laterally by slighter carinæ between the middle and posterior pairs, basally by a bisinuate carina between the latter pair, the ocellar space itself being longitudinally carinate; five carinæ behind the posterior ocelli, interrupted by a longitudinal sulcus on vertex, not extending quite to base of head, remainder of vertex irregularly transcarinate and punctate, especially laterally; occiput smooth with a row of punctures; posterior margin of head strongly bordered. Scape longer than cheeks; second flagellar joint one and a half times as long as first; third shorter than first and second together. Neck rather short, laterally transcarinate, semiannular smooth, apically and laterally punctate. Mesonotum centrally smooth, with three rows of rather large punctures, apically and laterally punctate. Central lobe of scutellum smooth, with large marginal punctures, lateral lobes diffusely punctate. Propleuræ transaciculate. Mesopleuræ basally rugose punctate,

apically indistinctly sculptured. Metapleuræ coarsely rugose punctate, narrowly smooth above, separated by a strong carina from the reticulate median segment. Petiole transstriate, shorter than the remaining smooth segments. Terebra as long as body, black. Hind coxæ transstriate, as long as the smooth bidentate femora; tibiæ much longer than femora, compressed to middle; metatarsi about three times as long as the remaining joints. Radius emitted from middle of stigma, its distal section nearly three times as long as the proximal.

Black; head dark red; base of mandibles, face, and outer orbits flavescent, frons and scape light red; vertex and the carinæ nigrescent; abdomen dark rufescent; anterior legs red; hind legs dark rufescent, their tarsi paler. Stigma and nervures brownish.

Length, 11 millimeters; abdomen, 7; petiole, 3; terebra, 11.

MINDANAO, Butuan (*Baker*).

The sculpture of the head and the shape of the ocellar space are distinctive; also the black carinæ on vertex.

PARASTEPHANELLUS VARIEGATUS sp. nov.

Female and male.—Frons basally arcuately, apically transversely striate, vertex very finely transstriate, with two carinæ, occiput smooth; posterior margin of head bordered; all tubercles distinct. Scape as long as cheeks; antennæ normal. Pronotum smooth, neck of average length. Mesonotum nearly smooth, with three distinct impressions. Scutellum and mesopleuræ smooth. Metapleuræ basally smooth, apically rugose, more regularly in female than in male, separated by an indistinct carina from the diffusely and superficially punctate median segment. Petiole transstriate, slightly longer than the remaining segments in female, as long in male. Terebra in female about as long as body, rufescent. Hind coxæ transstriate, a little longer than the smooth bidentate femora; tibiæ much longer than femora, compressed in basal two-fifths; metatarsi three times as long as the remaining joints in female, little longer in male. Radius emitted from apical fourth of the centrally hyaline stigma, its distal section more than three times as long as the proximal.

Dark red to black; head red, frons and base of antennæ paler; base of mandibles and the outer orbits white, ocellar space nigrescent; pronotum, petiole, base of second segment, and hind legs light red, anterior legs paler; middle metatarsi basally, hind ones entirely white.

Length: Female, 7.5 millimeters; abdomen, 4.5; petiole, 2.5; terebra, 8; male, 5 millimeters; abdomen, 3.5; petiole, 1.25.

MINDANAO, Kolambugan. BORNEO, Sandakan (*Baker*).

PARASTEPHANELLUS QUADRIDENS sp. nov.

Female.—Frons granulate, vertex finely transstriate, occiput smooth, finely longitudinally impressed; two carinæ behind the posterior ocelli; posterior margin of head bordered. Scape as long as cheeks; antennæ normal. Pronotum smooth, neck short, deeply impressed. Mesonotum with three distinct rows of punctures, between which it is punctate, the extreme lateral angles striate. Scutellum smooth. Mesopleuræ dull, with extremely fine transaciculation. Metapleuræ and median segment reticulate punctate, separated by a strong carina. Petiole transstriate, very little shorter than the remaining smooth shining segments. Terebra as long as body, black. Hind coxæ basally rugose, apically transstriate, rather shorter than the smooth femora, which bear two long sharp teeth, and behind them two unusually large blunt teeth, in addition to the usual smaller denticulations between and beyond the large ones; tibiæ much longer than femora, compressed to beyond middle; metatarsi three times as long as the remaining joints. Radius emitted from apical third of stigma, its distal section three times as long as the proximal.

Black; head, scape, and first flagellar joint red, vertex and occiput nigrescent; carinæ on vertex bright red; a pale line under eyes; anterior legs dark red, middle metatarsi basally, hind ones entirely white. Stigma and nervures dark red-brown.

Length, 15 millimeters; abdomen, 9.5; petiole, 4.5; terebra, 15.

MINDANAO, Kolambugan (*Baker*).

Male.—Agrees with female in sculpture and color. Petiole as long as rest of abdomen; metatarsi as long as the remaining joints.

Length, 12 millimeters; abdomen, 7; petiole, 3.5.

MINDANAO. Iligan (*Baker*).

The sculpture of the head, mesopleuræ, and hind coxæ is specific, also the femoral teeth.

PARASTEPHANELLUS CRASSICOXAE sp. nov.

Female.—Frons coarsely, subtransversely rugose, vertex transstriate, with four carinæ, occiput laterally smooth, centrally very finely transtriate, with a smooth central line; posterior margin of head finely bordered; posterior tubercles low and

broad; ocellar space longitudinally striate. Scape longer than cheeks, twice as long as the first, rather stout flagellar joint, third shorter than first and second together. Neck short, transstriate, half as long as the centrally punctate semiannular, which has a few transverse striæ, basally and laterally smooth. Mesonotum centrally punctate, with three rows of punctures, laterally rugose. Central lobe of scutellum centrally smooth, laterally diffusely punctate, as are also the lateral lobes. Pro- and mesopleuræ transaciculate. Metapleuræ basally and laterally smooth, with a broad central triangular space rugose punctate; median segment reticulate punctate, laterally finely rugose, separated from the metapleuræ by a carina, which is basally fine, coarser and less regular on apical half. Petiole rather coarsely transstriate, basally more rugose, shorter than the remaining smooth segments. Terebra slightly shorter than body, black. Hind coxæ very stout, rather finely transstriate, shorter than the transaciculate, bidentate femora; tibiæ much longer than femora, compressed slightly beyond middle; metatarsi not quite three times as long as the remaining joints. Radius emitted from just beyond middle of stigma, its distal section more than twice as long as the proximal.

Black; face, mandibles basally, cheeks, and base of antennæ rufotestaceous, outer orbits whitish; anterior legs rufotestaceous, middle tibiæ and metatarsi paler, hind trochanters and compressed part of hind tibiæ rufescent, their tarsi rufotestaceous.

Length, 12 millimeters; abdomen, 7.5; petiole, 3; terebra, nearly 12.

BASILAN (*Baker*).

Especially characterized by the very short, stout hind coxæ.

PARASTEPHANELLUS CRASSIFEMUR sp. nov.

Female.—Frons subgranulately, vertex finely and evenly transstriate, occiput bassally smooth, two carinæ on vertex; posterior margin of head finely bordered; all tubercles distinct. Scape as long as cheeks; antennæ normal. Pronotum smooth and shining, neck short. Mesonotum punctate with three fine impressions. Scutellum and mesopleuræ smooth. Metapleuræ mostly smooth, apical half centrally with large, superficial punctures, separated by a basally incomplete carina from the median segment, which is centrally smooth, otherwise superficially punctate. Petiole transstriate, shorter than the remaining smooth segments. Terebra much longer than body, black. Hind

coxæ irregularly transstriate, as long as the smooth, incrassate, bidentate femora; tibiæ not much longer than the femora, compressed in basal two-fifths; metatarsi three times as long as the remaining joints. Radius emitted from the apical third of stigma, its distal section four times as long as the proximal.

Black; head red, frons and base of antennæ rufotestaceous, vertex including the carinæ nigrescent, outer orbits white; anterior legs light red, hind ones rufescent, middle metatarsi rufescent, hind ones white. Stigma and nervures red-brown.

Length, 7.5 to 8 millimeters; abdomen, 4.5 to 5; petiole, 2 to 2.5; terebra, 11 to 12.

BORNEO, Sandakan. MINDANAO, Butuan (*Baker*).

PARASTEPHANELLUS CLARIPENNIS Cameron.

Parastephanellus claripennis CAMERON, Entomologist 44 (1911) 56.

PARASTEPHANELLUS FULGENS sp. nov.

Female.—Frons finely and evenly, vertex indistinctly transstriate, occiput smooth, posterior margin of head bordered; frontal tubercles well developed; one carina between posterior ocelli. Scape shorter than cheeks; first flagellar joint globose, the rest slender, second twice as long as first, third barely as long as first and second together. Pronotum, mesonotum, scutellum, and mesopleuræ smooth, mesonotum with three punctate impressions. Metapleuræ indistinctly transstriate, separated by an impression from the superficially and diffusely punctate median segment. Petiole extremely finely transstriate, as long as the remaining smooth, shining segments. Terebra much longer than body, rufescent. Hind coxæ slender, finely transstriate, apical half almost smooth, as long as the smooth, shining, bidentate femora; tibiæ much longer than femora, compressed to beyond middle; metatarsi more than twice as long as the remaining joints. Radius emitted from apical third of stigma, its distal section three times as long as the proximal.

Rufotestaceous; frons and vertex darker, outer orbits flavescent; carinæ on vertex bright red; antennæ blackish toward apex; extreme posterior margins of pronotum and scutellum nigrescent; abdomen from second segment rufescent; hind metatarsi whitish. Stigma and nervures brown-red, former basally hyaline.

Length, 7 millimeters; abdomen, 4; petiole, 2; terebra, 11.

MINDANAO, Dapitan (*Baker*).

This may be the female of my *P. leviceps* or *P. minutus*.

PARASTEPHANELLUS PALLIDITARSIS Cameron.

Parastephanellus palliditarsis CAMERON, Entomologist 44 (1911) 56. Female and male; ELLIOTT, Philip. Journ. Sci. 29 (1926) 756.

PARASTEPHANELLUS POLYCHROMUS Kieffer.

Parastephanellus polychromus KIEFFER, Philip. Journ. Sci. § D 9 (1926) 405. Female and male.

PARASTEPHANELLUS PARVUS sp. nov.

Female.—Frons and vertex transstriate, occiput mostly, two carinæ between posterior ocelli, posterior margin of head bordered; all tubercles distinct. Scape longer than cheeks; antennæ normal. Pronotum smooth, neck not very short. Mesonotum smooth, with three slightly punctate impressions. Scutellum and mesopleuræ smooth. Metapleuræ smooth above, otherwise punctate, separated by a slight carina from the indistinctly sculptured median segment. Petiole as long as the rest of the smooth abdomen. Terebra longer than body, black. Hind coxæ transstriate, as long as the bidentate femora; tibiæ compressed in basal two-fifths; metatarsi more than twice as long as the remaining joints. Radius emitted from apical third of the long, narrow stigma, its distal section more than twice as long as the proximal.

Black; head red, vertex nigrescent, frons rufotestaceous, outer orbits more or less flavescent; middle metatarsi basally, hind ones entirely white; hind coxæ black, legs otherwise rufescent.

Male.—The sculpture of the head, metapleuræ, and median segment is less distinct. Petiole longer than rest of abdomen; hind metatarsi about as long as the remaining joints.

Head red, frons and basal half of antennæ rufotestaceous; carinæ on vertex and apices of the frontal tubercles light red; outer orbits white.

Length: Female, 6 to 7.5 millimeters; abdomen, 4 to 5; petiole, 2 to 2.5; terebra, 8 to 8.5; male, 5.5 to 6 millimeters; abdomen, 3.5 to 4; petiole, 1.75 to 2.

BORNEO, Sandakan (*Baker*).

PARASTEPHANELLUS NIGER sp. nov.

Female and male.—Frons varies from finely transrugose to decidedly transstriate, vertex transstriate, occiput smooth; posterior margin of head bordered; two carinæ behind the posterior ocelli; all tubercles distinct. Scape as long as, or slightly longer than cheeks; antennæ normal. Neck short, laterally

more or less distinctly transstriate, semiannular smooth. Mesonotum rather large, smooth, with three impressions, sometimes laterally diffusely punctate. Scutellum and mesopleuræ smooth, latter sometimes basally transaciculate. Metapleuræ coarsely punctate, with a smooth space apically above, sometimes almost smooth basally, separated from the superficially punctate median segment by a carina, on each side of which is a line of more or less distinct punctures. Petiole finely transstriate, as long as the remaining smooth segments in female, slightly longer in male. Terebra in the female as long as, or slightly longer than body, black. Hind coxæ cylindrical, transstriate, rather longer than the smooth, bidentate femora; tibiæ longer than femora, compressed in basal three-fifths; metatarsi three times as long as the remaining joints in female, as long as, or very slightly longer than in male. Radius emitted from apical third of stigma, its distal section three times as long as the proximal.

Black; head brownish red to red, frons lighter or darker red, outer orbits flavescent, ocellar space and vertex nigrescent to black, carinæ on vertex red; legs black to rufescent, middle metatarsi sometimes basally, hind ones always entirely flavescent to white. Stigma and nervures red-brown to black.

Length: Female, 9 to 13 millimeters; abdomen, 5 to 8; petiole, 2.5 to 4; terebra, 11 to 14; male, 6 to 10 millimeters; abdomen, 3.5 to 6; petiole, 2 to 3.25.

MINDANAO, Dapitan. BORNEO, Sandakan. LUZON, Mount Limay. BASILAN (*Baker*).

The differences between the specimens are due chiefly to the degree of distinctness of the sculpture, and the depth of the color. I do not consider them sufficient to justify the erection of new species.

PARASTEPHANELLUS GLABERRIMUS sp. nov.

Male.—Frons and vertex extremely finely transstriate, occiput smooth, posterior margin of head bordered; two carinæ on vertex; posterior tubercles distinct. Scape as long as cheeks; antennæ normal. Pronotum and mesonotum smooth, latter with three almost impunctate impressions, the central one indistinct. Scutellum and mesopleuræ smooth. Metapleuræ almost smooth, separated by an impression from the superficially reticulate punctate median segment. Petiole finely transstriate, as long as rest of abdomen. Hind coxæ finely transstriate, femora smooth, tridentate; tibiæ much longer than femora, compressed in basal

three-fifths; metatarsi one and a half times as long as the remaining joints. Radius emitted from apical third of stigma, its distal section nearly four times as long as the proximal.

Black; head dark red; vertex nigrescent, frons and antennæ mostly rufotestaceous, outer orbits flavescent; carinæ on vertex bright red; anterior legs rufous, tarsi paler; hind legs rufescent, their metatarsi white. Stigma and nervures red-brown.

Length, 5 millimeters; abdomen, 3; petiole, 1.5.

BORNEO, Sandakan (*Baker*).

PARASTEPHANELLUS SINUATUS sp. nov.

Male.—Frons and vertex very finely, but not very distinctly transstriate, vertex smooth; one stout carina between the posterior ocelli; posterior margin of head bordered; all tubercles distinct. Scape as long as cheeks; antennæ normal. Neck rather long, transstriate finely, semiannular smooth. Mesonotum centrally strongly punctate, lateral angles carinate, three impressions, the lateral ones apically more finely punctate. Mesopleuræ smooth above, lightly punctate beneath. Metapleuræ rugose punctate, separated from the closely punctate median segment by a strong carina, with a row of short costæ on the outer side, and a line of punctures on the inner. Petiole finely transstriate, basally rugose, longer than the remaining segments, second segment basally rugose. Hind coxæ rather coarsely transstriate, fully as long as the smooth, bidentate femora; tibiæ much longer than femora, compressed to slightly beyond middle; metatarsi about as long as the remaining joints. Radius emitted from apical fourth of the rather broad stigma, its bisinuate basal section half as long as the distal; all nervures very strong.

Black; frons and scape light red, frontal tubercles and carinæ on vertex bright red; antennæ testaceous, apically darker; second segment red; hind femora and tibiæ rufescent, anterior legs and hind tarsi rufotestaceous. Stigma and nervures red brown.

Length, 10.5 millimeters; abdomen, 6.5; petiole, 3.5.

MINDANAO, Davao (*Baker*).

Characterized especially by the very strong nervures in forewing, and the bisinuate basal section of the radius. There are quadrate depressions between the short costæ on outer side of the carina bounding the median segment. Apparently closely allied to my *P. niger*.

PARASTEPHANELLUS MINUTUS sp. nov.

Male.—Frons extremely finely and closely transstriate, vertex and occiput smooth, former sometimes with traces of apical transstriation; no distinct carinæ on vertex; posterior tubercles subobsolete; posterior margin of head bordered. Scape as long as cheeks, third flagellar joint slightly shorter than first and second together. Pronotum smooth and shining, neck half as long as the semiannular. Mesonotum short, with the usual three impressions. Scutellum and mesopleuræ smooth and shining. Metapleuræ confusedly rugose, separated by a carina from the more or less distinctly reticulate punctate median segment. Petiole as long as the remaining smooth, shining segments. Hind coxæ finely transstriate, as long as the smooth, shining, bidentate femora; tibiæ much longer than femora, compressed to beyond middle; metatarsi as long as the remaining joints. Radius emitted from apical third of stigma, its distal section three times as long as the proximal.

Dark red; head rufotestaceous, frons often testaceous, vertex sometimes darker, outer orbits flavescent; pronotum, petiole sometimes, second abdominal segment, and anterior legs rufotestaceous, hind legs lighter or darker red, their tibiæ basally and the tarsi flavescent. Stigma and nervures red-brown.

Length, 5 to 6 millimeters; abdomen, 3 to 3.5; petiole, 1.5 to 1.75.

BORNEO, Sandakan. BASILAN (*Baker*).

The smooth vertex and the absence of a carina are characteristic. The black ocelli are especially conspicuous.

PARASTEPHANELLUS MACULIFRONS Cameron.

Parastephanellus maculifrons CAMERON, Journ. Straits Branch. Roy. Asiat. Soc. 37 (1902) 32; ELLIOTT, Proc. Zool. Soc. London (1922) 751.

PARASTEPHANELLUS LEVICEPS sp. nov.

Male.—Frons and vertex indistinctly transstriate, occiput smooth; one carina between posterior ocelli; posterior margin of head bordered laterally only, posterior tubercle obsolete. Scape as long as cheeks, first flagellar joint globose, second twice as long as first, third scarcely as long as first and second together. Pronotum smooth and shining, neck elongate. Mesonotum smooth, with three impressions, the central one indistinct. Scutellum and mesopleuræ smooth. Metapleuræ rugose, separated by a carina from the reticulate punctate median segment. Petiole finely transstriate, longer than the remain-

ing smooth segments. Hind coxæ transstriate; femora inflated, bidentate; tibiæ little longer than femora, compressed to beyond middle; metatarsi little longer than the remaining joints. Radius emitted from apical third of the rather broad stigma, its distal section more than twice as long as the proximal.

Rufescent; head red, vertex darker, outer orbits flavescent. Pronotum and anterior legs rufotestaceous, hind legs rufescent; hind tarsi flavescent. Stigma and nervures red-brown.

Length, 8.5 millimeters; abdomen, 5.5; petiole, 3.

BASILAN (*Baker*).

This species strongly resembles my *P. minutus*. It differs in larger size, stronger sculpture of head, metapleuræ, and median segment, in the presence of a carina on vertex, and in the much longer neck.

PARASTEPHANELLUS RUGIFRONS sp. nov.

Male.—Frons transrugose, vertex coarsely transstriate, occiput smooth; two carinæ behind posterior ocelli; posterior margin of head bordered; all tubercles distinct. Scape shorter than cheeks, third flagellar joint longer than first and second together. Pronotum smooth and shining. Mesonotum with three impressions, and a row of punctures on each side of the central one, lateral angles slightly rugose. Scutellum and mesopleuræ smooth. Metapleuræ rugose punctate, separated by a basally incomplete carina from the lightly, diffusely punctate median segment. Petiole transstriate, as long as the remaining smooth, shining segments. Hind coxæ finely transstriate, their femora smooth, bidentate; tibiæ much longer than femora, compresed in basal two-thirds; metatarsi scarcely longer than the remaining joints.

Radius emitted from apical third of stigma (apices of wings broken).

Black; head dark red, outer orbits flavescent; face, frons apically, three or four basal antennal joints, and anterior legs rufotestaceous; petiole and hind legs rufescent; carinæ on vertex and second abdominal segment light red; hind tarsi whitish. Stigma and nervures brown.

Length, 7 millimeters; abdomen, 4; petiole, 2.

BORNEO, Sandakan (*Baker*).

This may possibly prove to be the male of my *P. crassifemur*.

NEW OR LITTLE-KNOWN TIPULIDÆ FROM EASTERN ASIA (DIPTERA), II

By Charles P. Alexander
Of Amherst, Massachusetts[1]

TWO PLATES

The species considered at this time are virtually all from the mountains of Formosa, where they were collected chiefly by Prof. Syuti Issiki. An additional Formosan species was included in the extensive collections of crane flies made in August, 1921, by Prof. Teiso Esaki. A few species are from Kiushiu and Shikoku Islands, Japan, where they were collected by Messrs. Issiki and Uyē. One interesting form that is made the type of a new genus, *Riedelomyia,* was included in the very extensive collections of the Indian Museum, Calcutta, kindly loaned to me for study by the custodians, Messrs. Chopra and Singh Pruthi. I wish to thank all of the above-mentioned students for this kind coöperation in making known the very involved tipulid fauna of the Orient. Except where stated to the contrary, the types of the novelties herein described are preserved in my collection.

In this paper and all others prepared subsequent to 1926, I have adopted the modification of the radial field of the wing suggested by myself in other papers, especially in the extended account published in 1927.[2] At the same time, the rearrangement of tribes and subtribes based on the apparent phylogenetic relationships of the groups is adopted, this arrangement placing the Tipulinæ and the Cylindrotominæ at the beginning of the consideration and in much closer relationship to the tribe Limoniini than was realized earlier.

[1] Contribution from the Department of Entomology, Massachusetts Agricultural College.

[2] Proc. Linn. Soc. New South Wales 52 (1927) 42–72, 92 figs.

TIPULINÆ

NESOPEZA CIRCE sp. nov.

General coloration brown; antennæ pale; wings gray with an extensive brown pattern, each mark bordered by a conspicuous whitish ring; a circular marginal area in cell 1st A remote from the veins; Sc_1 far before the tip of Sc_2; R_2 and r in perfect transverse alignment; forks of media short.

Male.—Length, about 9.5 millimeters; wing, 8.8.

Female.—Length, about 12 millimeters; wing, 11.

Rostrum and palpi dark brown. Antennæ with the scapal segments brown; flagellar segments pale yellow, vaguely darkened outwardly; flagellar segments cylindrical. Head grayish brown.

Pronotum dark brown. Mesonotal præscutum brownish testaceous with three darker brown stripes, the median one broad; scutum brownish testaceous, each lobe with two darker brown areas, the posterior one larger; scutellum brown, narrowly margined with brownish testaceous; postnotum brown, paler laterally. Propleura, anepisternum, sternopleurite, and meron dark brown, the pteropleurite and pleurotergite paler, more testaceous brown. Halteres long, pale yellow, the knobs dark brown. Legs with the fore coxæ dark brown, the remaining coxæ a little paler; trochanters pale yellow; remainder of legs broken. Wings with the ground color gray, with an extensive bright brown pattern, each marking broadly and conspicuously bordered with white to produce a remarkably beautiful pattern; cell C and outer end of cell Sc whitish. The brown areas are distributed as follows: Prearcular region except a small white spot before h; a large postarcular cloud, including all the cells except C, sparsely variegated with white in the bases of cells M, 1st A, and 2d A; a large area at near one-third the length of cell R; origin of Rs; a conspicuous band along the cord, completely traversing the wing but almost interrupted at M; wing tip in cells R_2, R_3, R_5, and M_1, each of these with a conspicuous white inclosed area near outer end; a large circular marginal area in cell 1st A, remote from either vein, inclosing a tiny white nucleus which lies on the wing margin; tips of veins M_2, M_3, M_4, and 2d A, with small brown spots, similarly encircled with white; a small area on Sc_1; veins brown. A single small obliterative area traverses the basal section of M_{1+2} near midlength. Venation (Plate 1, figs. 1, 1*a*): Sc_1 far before the tip of Sc_2, the latter nearly twice m-cu; Rs relatively

short, angulated and weakly spurred at origin, subequal to R_3; R_{2+3} about one-half R_3; basal section of R_2 long, perpendicular, in alignment with the similarly transverse r, the distal section of R_2 entirely atrophied; distal section of R_1 without macrotrichiæ; R_3 gently arcuated; forks of the radial veins relatively short.

Abdominal tergites brown, variegated laterally at base with restricted yellow markings; outer segments more uniformly darkened; sternites dark, segments 3 and 4 with a conspicuous yellow crossband on the posterior half, the extreme caudal margins of the segments narrowly blackened. In the female, the pale coloration is dirty white and less evident. Ovipositor with short, stout valves, the sternal valves ending in short needlelike points.

Habitat.—Formosa.

Holotype, male, Mount Rantaizan, altitude 4,000 feet, June 2, 1927 (*S. Issiki*). Allotopotype, female.

Nesopeza circe is very distinct from all described members of the genus. The details of venation, especially the position of Sc_1, together with the transverse alignment of r and the basal section of R_2, are noteworthy features.

TIPULA TETRACANTHA sp. nov.

General coloration dark, the base of the abdomen yellowish; antennal flagellum bicolorous, dark, the base of each segment yellow; wings yellowish brown, the stigma brown; male hypopygium with the outer dististyle a strongly curved rod that terminates in an acute spine; inner dististyle a flattened blade, the outer margin near base bearing two acute black spines.

Male.—Length, about 13 milimeters; wing, 17; antennæ, about 4.5.

Described from an alcoholic specimen.

Frontal prolongation of the head relatively short, obscure yellow, narrowly darkened medially; nasus long and slender; palpi pale. Antennæ of moderate length; scapal segments pale; flagellar segments dark brown, the basal enlargement of each segment yellow; only twelve antennal segments, the last very small. Vertex dark, the genæ pale.

Mesonotum dark, any pruinosity normally present invisible in the alcoholic type. Pleura dark, the pteropleurite and pleurotergite paler; dorsopleural region pale. Halteres pale. Legs long and slender; fore coxæ dark, the middle coxæ dark except

basally, the posterior coxæ pale; trochanters pale yellow; femora obscure yellow, the tips narrowly but conspicuously dark brown; tibiæ obscure yellow, darker outwardly, the tips dark brown; tarsi elongated, passing into dark brown. Wings with a yellowish brown suffusion, the base and cells C and Sc more yellowish; stigma oval, brown; obliterative areas relatively conspicuous, including one in the outer end of cell R, crossing cell 1st M_2 into the extreme base of cell M_3; veins brown. Venation: Basal section of R_2 very reduced; distal section entire; petiole of cell M_1 short, a trifle longer than m; cell 2d A relatively narrow.

Abdomen with the basal segments yellowish, the subterminal segments passing into pale brown, the outer segments, including the hypopygium, blackened. Male hypopygium of moderate size, the tergite entirely separate from the sternite; basistyle fused with the sternite except beneath. Ninth tergite (Plate 2, fig. 13, *t*) long, narrowed outwardly, the apex terminating in two blackened subspinulose lobes that are separated from one another by a small V-shaped notch. Outer dististyle (Plate 2, fig. 13, *o*) a strongly curved, flattened, semichitinized blade that narrows to an acute black spine. Inner dististyle a broadly compressed yellow blade, the outer ventral margin armed with two conspicuous black spines (Plate 2, fig. 13, *i*). Ninth sternite with an acute notch from which hang ventrad two slender fleshy lobes that bear conspicuous yellow setæ. Eighth sternite unarmed.

Habitat.—Japan.

Holotype, male, Shikoku, July 4, 1926 (*S. Issiki*).

CYLINDROTOMINÆ

LIOGMA PECTINICORNIS sp. nov.

General coloration pale yellow, the præscutum and scutum conspicuously marked with black; flagellar segments with long apical pectinations; wings nearly hyaline, the stigma pale brown.

Male.—Length, about 9 milimeters; wing, 9; antenna, about 4. Described from an alcoholic specimen.

Rostrum pale yellow; palpi pale. Antennæ with the scapal segments yellow, the flagellum a little darker; antennæ (Plate 2, fig. 22) sixteen-segmented, with thirteen branched segments, the formula being $2 + 13 + 1$; all flagellar segments except the last with a conspicuous slender branch at the extreme apex

of the segment, the longest (on flagellar segments 4 and 5) nearly as long as the segment; last branch short, scarcely one-fourth the segment; segments with conspicuous elongate verticils, including a group of four or five on the outer face of the segment before the branch; each branch terminates in two elongate setæ, that of the longest approximately two-thirds the branch; terminal segment elongate, simple. Head above brownish black, the remainder obscure yellow.

Pronotum and mesonotum pale yellow, the præscutum with three shiny black stripes, the lateral stripes crossing the suture onto the scutal lobes. Pleura yellow. Halteres pale. Legs with the coxæ and trochanters yellow; remainder of legs brownish yellow, with dark setæ, the terminal tarsal segments darker. Wings nearly hyaline, the stigma pale brown; veins dark brown. Venation: Sc_1 not reaching the margin, appearing as a long spur; Sc_2 opposite midlength of the basal section of R_{4+5}; tip of R_1 vaguely indicated; tip of R_2 atrophied; r-m short but distinct, m-cu close to the fork of M.

Abdomen light brown, the sternites paler.

Habitat.—Formosa.

Holotype, male, Musha, altitude about 3,500 feet, October 5, 1926 (*S. Issiki*).

Liogma pectinicornis marks the most extreme tendency toward serration of the antennæ in the Cylindrotominæ that has yet been discovered.

LIMONIINÆ

LIMONIA FRAUDULENTA sp. nov.

Thoracic dorsum shiny black; head obscure yellow, the vertex infuscated; antennæ moniliform; dorsal pleurites black, the ventral sclerites abruptly yellow; wings with a strong brown suffusion, the stigma darker; male hypopygium with the dorsal dististyle very reduced; tips of the gonapophyses obtuse.

Male.—Length, about 5 millimeters; wing, 5.5.

Described from an alcoholic specimen.

Rostrum and palpi very short, rostrum yellow; palpi dark brown and apparently only two-segmented. Antennæ with the first scapal segment obscure yellow, the remainder of the organ dark brown; basal flagellar segments subglobular, a little broader than long, distinctly separated so as to appear moniliform; outer segments passing into oval; terminal segment elongate, pointed at apex. Head pale yellow, the vertex infuscated, paling into yellow behind.

Pronotum pale yellow in front, shiny black behind. Mesonotum entirely shiny black; pleura black dorsally, abruptly pale yellow ventrally, the latter color including the sternopleurite and meron. Halteres dusky, the knobs obscure yellow. Legs with the coxæ and trochanters yellow; femora obscure yellow, the tips infuscated; tibiæ brownish yellow, the tips narrowly infuscated, tarsi obscure brownish yellow, the terminal segment blackened. Wings with a strong brownish suffusion, the oval stigma darker brown; veins dark brown. Venation (Plate 1, fig. 2): Sc long, Sc_1 ending just beyond midlength of Rs, Sc_2 at its tip; Rs about twice the basal deflection of R_{4+5}; distal section of R_1 and basal section of R_2 in approximate transverse alignment; cell 1st M_2 relatively small, shorter than the veins beyond it; m-cu subequal to the distal section of Cu_1, placed shortly before the fork of M.

Abdominal tergites dark brown; sternites similar, the caudal margins of the intermediate segments narrowly yellowish; subterminal segment brownish yellow; hypopygium dark. Male hypopygium (Plate 2, fig. 14) with the ninth tergite low, the caudal margin gently emarginate. Basistyle relatively slender, the mesal lobe very large. Ventral dististyle smaller than the basistyle, fleshy, the rostral prolongation long and conspicuous, near its base with a small tubercle that bears two closely approximated pale spines. Dorsal dististyle reduced to a very small, slender rod. Ædeagus broad, with very broad subtending lateral wings. Gonapophyses stout, flattened, their tips obtuse.

Habitat.—Formosa.

Holotype, male, west side of Mount Daibu, altitude 3,000 to 5,000 feet, mid-March, 1927 (*S. Issiki*).

In its polished black thorax, *Limonia fraudulenta* bears a conspicuous superficial resemblance to species of *Dicranomyia* of the *morio* group.

LIMONIA REMISSA sp. nov.

General coloration pale ocherous, anterior vertex silvery; mesonotal præscutum with three darker brown stripes; a dorsal longitudinal brown stripe on the thoracic pleura; wings pale brownish yellow with an extensive pattern of brown spots and seams; Sc long.

Male.—Length, about 7 millimeters; wing, 6.8.

Described from an alcoholic specimen.

Rostrum and palpi black. Antennæ with the first scapal segment black, the second a little paler; flagellum pale brown; flagellar segments oval, passing into elongate-oval; terminal segment elongate, nearly twice the penultimate. Anterior vertex silvery gray, with a small median tubercle; head behind blackened, the median area more silvery.

Pronotum pale ocherous above, dark brown laterally. Mesonotum pale ocherous, the præscutum with three darker brown stripes; scutal lobes and scutellum dark brown, the median area of the former paler; postnotum dark. Pleura yellow with a broad dark brown longitudinal stripe that extends from the cervical sclerites across the dorsal pleurites to the postnotum, including the pleurotergite; sternopleurite a little infuscated ventrally. Halteres relatively elongate, pale, the knobs infuscated. Legs with the coxæ obscure yellow; trochanters brownish yellow; femora brownish yellow, clearer yellow basally, the tips narrowly darker brown; tibiæ and tarsi darker brown, especially the distal segments of the latter. Wings with a pale brownish yellow suffusion, darker in the costal region and base of cell R; an extensive rich brown pattern, consisting of large spots and seams that are diffuse and poorly delimited, including the following: Base of cells R and M; a large area at origin of Rs, not reaching M; a smaller cloud at end of Sc, extending from the costa posteriorly almost across cell 1st R_1; the stigmal spot completely fusing with a broad seam along the cord and with conspicuous dusky seams that fill cells 2d R_1 and R_3 excepting a large pale spot beyond the stigma; a broad seam on the outer end of cell 1st M_2; large diffuse spots at ends of veins M_3, M_4, Cu_1, and the anal veins, becoming larger toward the wing base; veins pale brown, paler in the ground areas. Venation: Sc long, Sc_1 ending about opposite three-fifths the long Rs, Sc_2 not far from its tip; Rs angulated and short-spurred at origin; tip of R_1 in approximate alignment with R_2; cell 1st M_2 elongate, nearly as long as vein M_{1+2} beyond it; m-cu a little shorter than the distal section of Cu_1, placed shortly before the fork of M.

Abdominal tergites dark brown, the incisures restrictedly pale; sternites 1 to 4 with the basal third or more conspicuously pale yellow. Male hypopygium (Plate 2, fig. 15) with the basistyle relatively large, the mesal lobe large, obtuse. Ventral dististyle smaller than the basistyle, pale, the apex bilobed, the outer or lateral portion setiferous, the inner portion larger,

produced mesally into a flattened beaklike rostrum; on the side of this inner lobule an oval area that is densely set with conspicuous tawny setæ; outer face of the rostrum with a similar fringe of setæ. Dorsal dististyle a relatively slender, curved chitinized rod, the tip acute, decurved. Gonapophyses very broad and flattened, the mesal apical angle produced caudad into a nearly straight slender lobe. Ædeagus broad.

Habitat.—Formosa.

Holotype, male, Musha, altitude about 3,500 feet, October 5, 1926 (*S. Issiki*).

LIMONIA EBRIOLA sp. nov.

General coloration dark brown; antennæ dark brown throughout; halteres and legs dark brown; wings with a strong brown suffusion, the stigma and seams on the transverse veins darker brown; male hypopygium with the spines of the rostral prolongation of the ventral dististyle long, slender, widely separated.

Male.—Length, about 6.2 millimeters; wing, 8.

Rostrum and palpi dark brown. Antennæ dark brown; flagellar segments oval, becoming more elongate-oval outwardly, with long conspicuous verticils. Head dark brown.

Pronotum dark brown. Mesonotum brown, the præscutal stripes somewhat darker brown, the surface sparsely yellowish pollinose, brighter sublaterally. Pleura dark brown, the surface pruinose, leaving narrow longitudinal stripes of the ground color on the sternopleurite and across the ventral anepisternum and pteropleurite; dorsopleural region broadly paler brown. Halteres dark brown, the base of the stem yellow. Legs with the fore coxæ brown, remaining coxæ yellow; trochanter yellow; remainder of legs dark brown, the femoral bases a little brighter. Wings with a strong brown suffusion, the oval stigma darker brown; narrow but conspicuous brown seams at origin of Rs, along the cord and outer end of cell 1st M_2; veins dark brown. Venation (Plate 1, fig. 3): Sc relatively short, Sc_1 ending about opposite one-third the length of Rs, Sc_2 not far from its tip. Rs weakly angulated near extreme origin; tip of R_1 distinct but pale; r and basal section of R_2 meeting angularly; cell 1st M_2 relatively short, rectangular, shorter than the veins issuing from it; m-cu close to the fork of M.

Abdominal tergites brownish black; basal sternites yellowish brown, the caudal margins brighter; subterminal segments brighter; hypopygium dark. Male hypopygium (Plate 2, fig. 16) with the caudal margin of the ninth tergite produced into

two obtuse lobes that are conspicuously setiferous. Basistyle of moderate size, its mesal lobe large. Dorsal dististyle a strongly curved sickle-shaped hook. Ventral dististyle large and fleshly, with numerous microscopic setulæ and more sparse long setæ; rostral prolongation stout, the two slender spines widely separated; outer spine arising from a short enlarged base, gently curved; inner spine a little shorter and more nearly straight; space between the spines with sparse erect setulæ. Gonapophyses pale, broadly expanded, the mesal apical angle produced into a long, slender, gently curved rod.

Habitat.—Formosa.

Holotype, male, Mount Rantaizan, altitude 6,000 feet, June 3, 1927 (*S. Issiki*).

DICRANOMYIA CINGULIFERA sp. nov.

General coloration dark brown; rostrum relatively elongate; antennæ dark brown, the second segment pale yellow; pleura silvery gray with two longitudinal dark brown stripes; halteres yellow, the knobs dark brown; femora obscure yellow with a dark brown subterminal ring; wings whitish subhyaline, heavily variegated with dark brown, especially beyond the cord; Sc elongate; abdomen brownish black, the segments ringed caudally with silvery gray.

Female.—Length, 5.5 to 6 millimeters; wing, 5 to 5.8.

Rostrum relatively elongate, approximately as long as, or a little longer than, the remainder of the head, black; palpi black. Antennæ with the first scapal segment dark brown; second segment pale yellow; flagellum dark brown, the segments short-oval, the outer segments smaller and more nearly globular; terminal segment longer, the apex pointed. Head brownish gray.

Pronotum brown, with a yellowish pollen. Mesonotal præscutum yellowish gray, clearer gray laterally, with four narrow dark brown stripes, the intermediate stripes narrower, separated from one another by a slightly narrower line of the ground color; a circular brown spot near the lateral margin behind the pseudosutural foveæ; scutum yellowish gray, the centers of the lobes darker; scutellum and postnotum brownish gray, the latter darker behind. Pleura silvery gray, variegated with two longitudinal dark brown stripes, the narrow dorsal stripe crossing the ventral propleura and anepisternum, the broader ventral stripe including the ventral protion of the sternopleurite. Hal-

teres pale yellow, the knobs dark brown. Legs with the coxæ brown, paler apically, the fore coxæ more reddish brown; trochanters yellowish testaceous; femora obscure yellow with a relatively broad dark brown subterminal ring, the extreme tip narrowly pale yellow; tibiæ and basitarsi brownish yellow, the tips narrowly infuscated; remainder of tarsi darker brown. Wings whitish subhyaline, the base and costal region a trifle more yellowish; a conspicuous dark brown pattern that is much heavier beyond the cord; seams on h; Sc_2; a large spot beyond arculus; an elongate rectangular area at origin of Rs, extending from costa almost to M, including the tip of Sc_1; stigma short-oval to subrectangular, connected with a narrow seam along the cord; outer ends of cells 2d R_1 and R_5 heavily infuscated; a narrow seam on outer end of cell 1st M_2; marginal brown spots on veins M_{1+2}, M_3, and M_4; smaller similar spots on Cu_1 and 1st A; a large marginal spot on vein 2d A; veins pale, darker in the infuscated areas. Venation: Sc_1 ending just beyond the origin of Rs, Sc_2 far from its tip, at near mid-distance between arculus and origin of Rs; Rs weakly angulated at origin; tip of R_1 and base of R_2 in approximate transverse alignment; cell 1st M_2 elongate-rectangular, subequal to vein M_{1+2} beyond it; elements closing the cell very faint; m-cu close to the fork of M, a little shorter than the distal section of Cu_1.

Abdomen brownish black, the segments broadly and conspicuously ringed caudally with silvery gray; base of genital segment blackened; valves of ovipositor relatively small, nearly straight, reddish horn color.

Habitat.—Formosa.

Holotype, female, Mount Rantaizan, altitude 7,000 feet, June 2, 1927 (*S. Issiki*). Paratopotypes, two females, with the type; one female, 6,000 feet, June 3, 1927.

DICRANOMYIA FRIVOLA sp. nov.

Female.—Length, about 6.5 millimeters; wing, 7.6, its greatest width, 2.2.

Belongs to the *pulchripennis* group, most closely allied to *D. shirakii* Alexander, from which it differs especially in the broader wings with the white ground color more extensive.

Antennal flagellum weakly bicolorous, the ground color of the basal segments obscure yellow, the outer segments brownish black with the bases narrowly pale. Femoral tips, tibial bases, and tibial tips broadly and conspicuously blackened. Wings

broad, as shown by the above measurements; whitish, the extreme base a little more yellowish; costal pattern as in *shirakii,* with five extensive costal blotches, the first three of which are entire and more or less T-shaped, the caudal extension of each blotch in cell R being much narrower than the dilated costal portion; the white ground color separating these dark costal areas wider than in *shirakii;* cell R_3 and the cephalic portion of R_5 with clearly defined, relatively small, dark brown spots that do not tend to become confluent; cells 2d M_2, M_3, and M_4 with the ground color more extensive, the dark pattern more contrasted.

The cells of the wing are wider than in *shirakii* due to the greater breadth of the wing; cell 1st M_2 relatively short, its lower face shorter than vein M_4 beyond it; m-cu more than one-half its length before the fork of M.

Habitat.—Formosa.

Holotype, female, Mount Rantaizan, altitude 7,000 feet, June 3, 1927 (*S. Issiki*).

DICRANOMYIA NESOMORIO sp. nov.

Belongs to the *morio* group; male hypopygium with the caudal margin of the ninth tergite bearing two widely separated slender lobes; mesal lobe of basistyle long and slender; dorsal dististyle bifid at apex.

Male.—Length, about 5 to 5.5 millimeters; wing, 6 to 6.8.

Rostrum and palpi black. Antennæ black throughout; flagellar segments oval, the outer segments becoming more elongate-oval. Head black, the anterior vertex silvery, the posterior vertex narrowly grayish.

Pronotum black, sparsely pruinose. Mesonotum shiny black, especially the præscutum; median region of scutum, scutellum, and postnotum more pruinose. Pleura black, heavily silvery pruinose. Halteres elongate, dark brown, the base of the stem narrowly pale. Legs with the fore and middle coxæ brownish black, pruinose, paler apically, the posterior coxæ uniformly pale; trochanters reddish yellow; remainder of the legs black, the femoral bases restrictedly obscure yellow. Wings with a strong brownish tinge, the oval stigma darker brown; very vague and narrow dusky seams on the cord; veins darker brown. Venation: Sc_1 ending just beyond the origin of the long Rs; distal section of R_1 weakly preserved, lying a little basad of the equally pale basal section of R_2, r thus being preserved and

provided with two or three macrotrichiæ; cell 1st M_2 closed, a little shorter than vein M_{1+2} beyond it; m-cu subequal to the distal section of Cu_1, lying shortly before the fork of M.

Abdomen black, the caudal margins of the tergites broadly brown; sternites black, the caudal margins of segments 2 to 5 broadly yellowish brown; hypopygium dark. Male hypopygium (Plate 2, fig. 17) with the ninth tergite having the caudal margin terminating in two long slender lobes, widely separated by a broad U-shaped notch, the tips of the lobes with conspicuous setæ. Basistyle relatively small, dark, bearing a small subterminal tubercle on dorsal mesal margin; mesal lobe very long and slender, narrowed gradually to the subacute apex, paler than the remainder of the style. Ventral dististyle larger than the basistyle, fleshly, the rostral prolongation bearing a single stout pale spine near base. Dorsal dististyle gently curved, the tip bifid, the outer spine obtuse, the inner spine acute. Gonapophyses small.

Habitat.—Formosa.

Holotype, male, Mount Rantaizan, altitude 6,000 feet, June 2, 1927 (*S. Issiki*). Paratopotype, male; paratype, male, Rengechi, altitude 1,500 to 2,000 feet, end of March, 1927 (*S. Issiki*).

Genus PROTOHELIUS novum

Rostrum short, not produced; palpi four-segmented, conspicuous, the terminal segment nearly twice the penultimate, slender. Antennæ sixteen-segmented; flagellar segments long-cylindrical, gradually decreasing in length and diameter outwardly; terminal segment about one-half the penultimate; verticils relatively inconspicuous, not longer than the segments. Anterior vertex relatively narrow, about one-third wider than the diameter of the first scapal segment, subequal in both sexes; eyes relatively large and protuberant, with delicate ommatidia. Pronotum relatively massive. Legs comparatively stout; no tibial spurs; claws simple; empodia distinct. Wings (Plate 1, figs. 5, 5*a*) broad; Sc long, Sc_1 ending beyond midlength of R_{2+3}, Sc_2 about opposite the fork of Rs; tip of R_1 preserved; r short; basal section of R_2 preserved, perpendicular or even slightly recurrent at origin, the distal section preserved, without macrotrichiæ; tips of Sc_1, R_1, and R_2 all relatively close together at wing margin; R_{2+3} a little longer than the basal section of R_{4+5}; cell 1st M_2 closed, irregularly pentagonal; m-cu at the

fork of M, subequal to the distal section of Cu_1; cell 2d A wide; h very faint, oblique. Male hypopygium (Plate 2, fig. 18) with the basistyle short and stout. Outer dististyle broad-based, narrowed into an elongate blackened tip, on the mesal face near midlength with a short blunt blackened lobe. Inner dististyle of almost the same length and form as the outer, terminating in a long pale outer lobe and bearing a shorter lateral fleshy lobe on mesal face near base. Phallosome modified into a cylindrical structure. Ovipositor with the valves long and straight, the tips of the tergal valves gently upcurved.

Genotype, *Protohelius issikii* sp. nov. (Oriental Region.)

Protohelius is of extreme importance in that it indicates the manner in which the radial field in the more-aberrant subtribes of the Limoniini (such as the Heliaria, Dicranoptycharia, Tonnoiromyaria, and Aphilimnobaria) may have been derived. From a study of this genus, it appears that it is usually the free tip of R_1 that atrophies, leaving the distal end of R_2 persistent.

PROTOHELIUS ISSIKII sp. nov.

General coloration yellow, the thoracic dorsum extensively shiny black; wings broad, grayish brown, the stigma darker; abdomen dark brown, the basal sternites yellow.

Male.—Length, about 8.5 millimeters; wing, about 10.

Female.—Length, about 10 to 10.5 millimeters; wing, 10.5 $\times$ 3.2.

Described from alcoholic specimens.

Rostrum pale, the palpi dark brown, the terminal segment paler apically. Antennæ with the scapal segments brownish yellow, the flagellum dark brown. Head dark brown, paler beneath.

Pronotum yellow. Mesonotum almost covered by a shiny black dorsal shield, the lateral margins of the præscutum broadly yellow; central portion of the transverse suture pale; lateral margins of the scutal lobes and the parascutella pale yellow. Pleura pale yellow, including the pleurotergite, the ventral sternopleurite darkened. Halteres pale, the knobs weakly darkened. Legs relatively stout; coxæ and trochanters yellow; femora yellow basally, passing into dark brown; remainder of legs yellowish brown, the terminal tarsal segments darker brown; tarsal segments 3 and 4 each with a stout spinous bristle near apex. Wings broad, with a grayish brown suffusion,

the prearcular region more yellowish; cells Sc and Cu_1 darker; stigma brown; veins darker than the ground color. Venation (Plate 1, figs. 5, 5*a*) as discussed under the genus.

Abdomen dark brown, the basal sternites yellow, the intermediate sternites with the lateral margins pale; hypopygium pale. Female with the genital segment horn yellow, the valves darker.

Habitat.—Formosa.

Holotype, male, Rengechi, altitude 1,500 to 2,000 feet, end of March, 1927 (*S. Issiki*). Allotopotype, female. Paratopotypes, one male, one female.

This peculiarly interesting type of crane fly is named in honor of my friend Prof. Syuti Issiki, to whom I am greatly indebted for coöperation in studying the crane flies of Japan and Formosa.

HELIUS RUFITHORAX sp. nov.

Rostrum elongate; head dark gray; mesonotum and pleura shiny ferruginous, without markings; wings grayish subhyaline, the base and costal region more yellowish; abdominal tergites with the distal segments uniformly blackened, this including the hypopygium.

Male.—Length (excluding rostrum), about 7.5 millimeters; wing, 8.6; rostrum, 2.8.

Female.—Length (excluding rostrum), about 8 millimeters; wing, 9 to 9.5; rostrum, 2.8.

Rostrum elongate, approximately equal to the combined head and thorax, black throughout; palpi black. Antennæ brownish black, the second scapal segment a little paler. Head dark gray, the anterior vertex narrow.

Mesonotum shiny ferruginous, without markings. Pleura shiny yellowish ferruginous. Halteres pale, the knobs infuscated. Legs with the coxæ concolorous with the pleura; trochanters a little more yellowish testaceous; femora obscure yellow, the tips narrowly blackened; tibiæ obscure brownish yellow, the tips very narrowly darkened; tarsi brown, the terminal two segments darker. Wings grayish yellow subhyaline, the base and cells C and Sc clearer yellow; stigma oval, dark brown; wing tip in cells 2d R_1 and R_3 narrowly darkened; a narrow vague seam on the anterior cord; a conspicuous dusky seam along vein Cu; veins brown, brighter in the basal and costal regions. Venation: Sc_1 ending opposite the fork of Rs, Sc_2

at its tip; r-m distinct; cell 1st M_2 relatively broad, subrectangular; m-cu shortly beyond the fork of M.

Abdomen with the basal tergites brownish yellow, the caudal margins of the segments darkened; outer four or five segments, including the hypopygium, uniformly blackened. Female with the tergites uniformly dark brown, the basal sternites obscure brownish yellow.

Habitat.—Formosa.

Holotype, male, Mount Rantaizan, altitude 7,000 feet, June 4, 1927 (*S. Issiki*). Allotopotype, female, 6,000 feet, June 3, 1927. Paratopotype, female, with the type.

Helius rufithorax is allied to the smaller *H. tenuirostris* Alexander, differing in the longer rostrum, the uniform thorax, the unvariegated abdominal segments, black hypopygium, and other characters.

EURHAMPHIDIA INELEGANS sp. nov.

General coloration pale brown, the mesonotum darker; head dark; legs with the femoral tips yellow; tibial bases very narrowly pale; tips of the tibiæ and most of the tarsi white; wings subhyaline, the stigma pale brown; Sc relatively long, veins R_3 and R_{4+5} strongly divergent.

Female.—Length, about 6 millimeters; wing, 5.3.

Described from an alcoholic specimen.

Rostrum obscure yellow, the apex darker; palpi dark brown. Antennæ with the first scapal segment yellow, the second dark brown; flagellum pale brown, the outer segments broken. Head dark brown.

Pronotum pale brown, yellowish laterally. Mesonotum pale brown, the præscutum with a broad median and narrower lateral stripes of a darker color; remainder of mesonotum chiefly dark brown. Pleura obscure yellow, sparsely variegated with brown on the sternopleurite and pleurotergite. Halteres pale brown, the base of the stem brighter. Legs with the coxæ obscure yellow, the outer faces more or less infuscated; trochanters obscure brownish yellow; femora pale brown, the tips paling into yellow; tibiæ darker brown, the extreme bases vaguely paler, the tips whitened; tarsi pure white, excepting the terminal two segments which are infuscated. Wings (Plate 1, fig. 4) subhyaline; cells C and Sc a trifle more yellowish; stigma oval, relatively small, pale brown; veins brown. Wings relatively short and broad, more so than in *E. abnormalis*

(Brunetti), the cells correspondingly widened, the prearcular cells shortened. Vein M_1 without macrotrichiæ. Venation: Sc relatively long, Sc_1 ending about opposite one-fourth the second section of Rs, Sc_2 longer, ending about opposite one-third the same; second section of Rs approximately three-fourths the first; veins R_3 and R_{4+5} strongly divergent and relatively short, cell R_3 at margin wide; m-cu at near two-thirds the length of cell 1st M_2.

Abdominal tergites pale brown, the sternites obscure yellow. Ovipositor with the valves strongly infuscated; tergal valves straight, the tips a little upcurved.

Habitat.—Formosa.

Holotype, female, Musha, altitude about 3,500 feet, October 5, 1926 (*S. Issiki*).

Eurhamphidia inelegans has the pattern of the femora and bases of the tibiæ much more obscured and ill-defined than either *E. niveitarsis* (Skuse) or *E. abnormalis* (Brunetti).

DICRANOPTYCHA FORMOSENSIS sp. nov.

General coloration brownish gray, the thoracic pleura pale with the anepisternum darker; legs yellow, the tips of the segments very narrowly and inconspicuously blackened; wings grayish yellow, the costal region clearer yellow; costal fringe short; male hypopygium with the outer dististyle densely set with short setæ, terminating in an acute black spine; gonapophyses elongate, terminating in a unilateral brush of long setæ.

Male.—Length, about 8 millimeters; wing, 9.2.

Female.—Length, about 9.5 to 10 millimeters; wing, 10.2 to 10.5.

Rostrum reddish brown, the palpi dark brown. Antennæ reddish brown, the outer segments darker, feebly bicolorous, the joints being paler than the central portion of each segment. Head brownish gray.

Mesonotal præscutum brownish gray, the median area of the præscutum somewhat brighter brown; pseudosutural foveæ black; scutum brownish gray; scutellum a little more reddish brown, pruinose; postnotum more heavily pruinose. Pleura pale, the anepisternum darker, the surface sparsely pruinose, in the paratype more heavily so. Halteres pale yellow, the knobs scarcely darker. Legs with the coxæ pale, very sparsely pruinose; trochanters yellow; remainder of legs yellow, the extreme tips of the femora on the outer face, the similarly narrow tips of the tibiæ and basitarsi, and the terminal tarsal segments

brownish black. Wings with a grayish yellow suffusion, the prearcular and costal regions clearer yellow; veins brownish yellow; costal fringe (male) short. Venation: Rs from one-third to one-half longer than cell 1st M_2; m-cu at near midlength of cell 1st M_2.

Abdomen with the basal tergite dark brown; remaining segments obscure yellow, dark brown laterally; a subterminal dark brown ring; hypopygium yellow; sternites similar, the basal segments obscure yellow. Male hypopygium (Plate 2, fig. 19) with the outer dististyle a compressed elongate blade, densely set with relatively short setæ, the apex of the style narrowed into a long curved black spine. Inner dististyle longer, appearing as a flattened, parallel-sided elongate rod, the tip obtuse, the inner face set with erect spinous setæ. Gonapophyses very conspicuous, appearing as long taillike rods that are provided just before their tips with very long spinous setæ, arranged to form a subapical unilateral brush.

Habitat.—Formosa.

Holotype, male, Ranrun, altitude 1,000 feet, June 2, 1927 (*S. Issiki*). Allotopotype, female. Paratopotype, female.

DICRANOPTYCHA GENICULATA sp. nov.

General coloration brownish black; ventral pleurites paler; legs yellow, the tips of the femora broadly brownish black; bases and tips of the tibiæ similarly blackened; wings brownish, the bases and costal region more yellowish; costal fringe short; abdomen brownish black, the hypopygium obscure yellow; male hypopygium with outer dististyle having the outer surface spinous; gonapophyses elongate, the surface smooth.

Male.—Length, about 10 millimeters; wing, 9 to 9.5.

Female.—Length, about 12 millimeters; wing, 10.

Described from alcoholic specimens.

Rostrum brownish testaceous, the palpi dark brown. Antennæ dark brown throughout, relatively long in both sexes; first flagellar segment approximately twice the length of the second; succeeding segments gradually becoming more elongate to the penultimate, the terminal segment about two-thirds the penultimate; verticils conspicuous, exceeding the segments in length. Head dark brown, with long yellow setæ, the occiput paler.

Mesonotum dark brown, the humeral region of the præscutum brighter; in cases the cephalic portion of the præscutum is paler, the posterior portion being largely covered by three

brownish black stripes. Pleura dark, the ventral pleurites paler, obscure yellow. Halteres pale, the base of the knobs darker. Legs with the coxæ and trochanters yellow; femora yellow, the tips broadly brownish black, the amount subequal on all the legs (about 1.25 millimeters); tibiæ yellow with the base narrowly, the apex more broadly brownish black; tarsal segments 1 and 2 obscure yellow, the tips brownish black; terminal tarsal segments uniformly darkened; legs with long, conspicuous, semi-erect setæ. Wings with a strong brown suffusion, the base and costal region more yellowish, cell Sc clearer yellow than cell C, the outer costa and stigmal region more infumed; veins pale brown, more yellowish in the costal region and along vein Cu; costal fringe (male) short. Venation: Rs relatively short, subequal to cell 1st M_2; m-cu at or not far beyond the fork of M, the first section of M_{3+4} subequal to or shorter than r-m.

Abdomen brownish black, the hypopygium obscure yellow. Male hypopygium (Plate 2, fig. 20) with the outer dististyle a curved rod, the apex produced into a stout blackened point, the outer surface with conspicuous erect spinous tubercles that form a low crest, the spines becoming smaller basally. Inner dististyle short and stout, fleshy, a little shorter than the outer dististyle, provided with long conspicuous setæ. Gonapophyses long and slender, sinuous, the apex unarmed. Ovipositor with the valves very short; tergal valves with the distal half blackened.

Habitat.—Formosa.

Holotype, male, without exact locality data, October, 1926 (*S. Issiki*). Allotopotype, female. Paratopotype, male.

PROANTOCHA UYEI sp. nov.

General coloration obscure yellow, variegated with dark brown; all legs provided with short spinous setæ; posterior femora conspicuously flattened, the apical tooth low and obtuse; posterior tibiæ elongate, conspicuously clavate at tip, the basal tooth slender; wings whitish subhyaline, the costal region more yellowish.

Male.—Length, about 7 millimeters; wing, 10.5. Fore leg, femur, 6.7; tibia, 9; tarsus, about 4.6. Middle leg, femur, 6.8; tibia, 6.7; tarsus, about 2.9. Hind leg, femur, 7.2; tibia, 11.7; tarsus, about 2.7.

Other specimens show a range in length from about 6 to 7.5 millimeters, the wing, 9 to 11, with the measurements of the segments of the legs in proportion.

Rostrum obscure brownish yellow, the palpi dark brown. Antennæ with the basal segment brown, obscure yellow basally, the remainder of the organ dark brown; flagellar segments oval with short verticils and a short erect pubescence; terminal segment elongate. Head brownish gray, more yellowish on the orbits.

Pronotum dark brown, paler laterally. Mesonotal præscutum obscure yellow with three brown stripes, the median stripe becoming obsolete before the suture; lateral stripes paler than the median, crossing the suture onto the scutal lobes; scutum broadly pale medially; scutellum broad, pale, with a dusky spot on either side at base; postnotal mediotergite dark, pruinose medially and behind, with a small yellow spot on either side at base. Pleura brownish yellow, conspicuously variegated with dark brown on the propleura, ventral anepisternum, the ventral sternopleurite, the dorsal pteropleurite, and the meron; pleurotergite largely pale, the ventral portion darkened. In other specimens the pleura is more uniformly darkened. Halteres pale, the knobs more or less infuscated. Legs with the coxæ pale, narrowly darker basally, the posterior coxæ large; trochanters obscure yellow; remainder of legs dark brownish yellow, the tarsi beyond the base dark brown; proportions of the segments of the legs shown by the above measurements; fore and middle legs unmodified, provided with a dense vestiture of very short spinous setæ; fore tarsi longest; posterior femora conspicuously flattened, the apical tooth low and obtuse; tibiæ with a slender basal tooth, as in the males of this genus; posterior tibiæ conspicuously clavate at tip; posterior tarsi very short; claws toothed. Wings whitish subhyaline, the costal region more yellowish; stigma faintly indicated, elongate, pale brown; vein Cu indistinctly seamed with dusky; prearcular veins pale; costal veins yellowish, remaining veins dark brown. Venation: Veins strong; basal section of R_2 nearly in alignment with r-m; m-cu shortly before the fork of M.

Abdomen dark brown, the intermediate segments narrowly margined caudally and laterally with yellow; basal sternites obscure yellow; hypopygium brownish yellow. Male hypopygium generally similar in structure to the other members of the genus.

Habitat.—Japan.

Holotype, male, Yamaga, Oita-ken, Kiushiu, on the banks of the Yasakawaga, altitude 225 feet, April 22, 1927 (*Tenji Uyē*). Paratopotypes, four males, April 21–22, 1927.

This interesting crane fly is named in honor of the collector, Mr. Tenji Uyē, to whom I am indebted for many crane flies from Kiushiu. *Proantocha uyēi* is very peculiar in the extreme modifications of the legs. The short, spinous vestiture of the fore and middle, as well as the posterior legs, together with the flattened posterior femora and clavate tibiæ readily distinguish the species from the two members of *Proantocha* hitherto made known (*P. spinifer* Alexander and *P. serricauda* Alexander, of Japan).

TRICYPHONA KIRISHIMENSIS sp. nov.

General coloration pale brownish yellow; antennæ yellow; head and apex of abdomen dark brown; legs yellow, the tips of the femora and tibiæ narrowly darkened; wings pale yellowish brown, the costal cell darker; r-m connecting with R_{4+5}; cell M_2 open.

Male.—Length, about 11.5 millimeters; wing, 13.6.

Described from an alcoholic specimen.

Rostrum and palpi brownish black. Antennæ sixteen-segmented, pale yellow, the extreme base of the first segment darkened, the terminal three or four segments dusky. Head dark brown.

Thorax pale brownish yellow, without distinct markings, the postnotum somewhat darker. Halteres relatively elongate, pale. Legs with the coxæ obscure yellow; trochanters brownish yellow; femora yellow, the tips narrowly dark brown; tibiæ brownish yellow, the tips narrowly dark brown; tarsi dark brown, the outer segments blackened. Wings with a pale yellowish brown suffusion, cell C more strongly infumed; stigma pale yellow, vaguely encircled by dusky; very restricted pale brown seams at origin of Rs and along the cord; veins dark brown. Venation (Plate 1, fig. 6): Sc_2 far before the origin of Rs, the latter angulated and spurred at origin; r-m connecting with R_{4+5} at near one-fourth the length; R^{2+3} elongate; R_{1+2} a little shorter than R_2; petiole of cell R_4 nearly equal to r-m; cell M_2 open by the atrophy of m; m-cu subequal to the distal section of M_{3+4}.

Abdominal tergites obscure brownish yellow, with a continuous narrow dark brown median stripe; outer segments and hypopygium passing into dark brown; sternites brownish yellow, the base of the individual segments narrowly clearer yellow. Male hypopygium with the dististyle very large, bilobed, each lobe slender, with no armature other than abundant setæ of

various lengths. Interbases appearing as long, slender, chitinized spines. Ædeagus and gonapophyses appearing as broad blades, their tips obtuse.

Habitat.—Japan.

Holotype, male, Mount Kirishima, Kiushiu, June 9, 1926 (*S. Issiki*).

The only similar Japanese species is *Tricyphona confluens* Alexander,[3] which differs in having the antennæ and legs dark brown; r-m connecting with Rs before its fork, and in other characters.

TRICYPHONA FORMOSANA Alexander.

Tricyphona formosana ALEXANDER, Ann. Ent. Soc. America 13 (1920) 260–261.

The type, a male, was from Arisan, Formosa, collected April 24, 1927, by Doctor Shiraki. The following additional records of occurrence of this small and inconspicuous but highly interesting crane fly are given: West side of Mount Daibu, Formosa, altitude 3,000 to 5,000 feet, mid-March, 1927 (*S. Issiki*). Mount Rantaizan, altitude 7,000 feet, June 2, 1927 (*S. Issiki*). The wing venation is shown on Plate 1, fig. 7.

PSEUDOLIMNOPHILA DESCRIPTA sp. nov.

General coloration dark brown; antennæ black; halteres dusky; wings with a strong brown suffusion, the stigma darker; Sc short; R_2 arising from R_{2+3+4}; cell M_1 lacking; cell 1st M_2 relatively short.

Female.—Length, about 6.5 millimeters; wing, 6.4.

Rostrum very short, dark brown; palpi black. Antennæ black throughout; flagellar segments with long conspicuous verticils that are more than twice as long as the segments bearing them. Head dark brown, the anterior vertex and narrow posterior orbits light gray.

Pronotum gray. Mesonotal præscutum brown, more grayish laterally, the humeral region a little brighter, the dorsum with three scarcely evident darker brown stripes; pseudosutural foveæ relatively pale, a little darker than the ground color; scutum dark brown; scutellum and postnotum more pruinose. Pleura dark, the surface sparsely pruinose. Halteres dusky, the stem restrictedly paler at base. Legs with the coxæ brownish testaceous, paler apically; femora brown, a little darker out-

[3] Insec. Inscit. Menst. 10 (1922) 186–187.

wardly, the bases more yellowish brown; tibiæ brown, the tips weakly darker; terminal tarsal segments darker brown. Wings with a strong brown suffusion, the elongate-oval stigma darker brown; veins darker brown. Venation (Plate 1, fig. 8): Sc_1 ending before the fork of Rs, Sc_2 at its tip; Rs relatively long, gently arcuated at origin; R_{2+3+4} elongate; R_2 longer than R_{3+4}; R_{1+2} more than twice R_2 alone; cell M_1 lacking; cell 1st M_2 relatively short, less than one-half cell 2d M_2 beyond it; m-cu just beyond the fork of M, shorter than the distal section of Cu_1; anterior arculus preserved.

Abdomen dark brown; sternites obscure yellowish brown. Ovipositor with the long valves darkened, the tips somewhat brighter colored.

Habitat.—Formosa.

Holotype, female, Mount Rantaizan, altitude 4,000 feet, June 2, 1927 (*S. Issiki*).

Genus LIMNOPHILA Macquart

Subgenus TRICHOLIMNOPHILA novum

Characters as in the genus, differing as follows: Antennæ ranging from short to moderately elongate (*platystyla*), in the latter case, the ventral face of the flagellar segments a little protuberant; longest verticils exceeding the segments in length. Pseudosutural foveæ and tuberculate pits both present. Legs with conspicuous trichiæ; tibial spurs distinct. Wings with Sc relatively short, Sc_1 ending shortly before the fork of Rs, Sc_2 not far from its tip; R_2 from one-third to one-half R_{1+2} and from one-half to two-thirds R_{2+3+4}; inner ends of cells R_4, R_5, and 1st M_2 in subtransverse to oblique alignment, in the latter case with cell 1st M_2 lying more basad; cell M_1 present; m-cu shortly before midlength of cell 1st M_2; anterior arculus preserved. Distal cells of wing (R_2 to M_3) with macrotrichiæ; in some species, these even more abundant, including the distal end of cell M_4 or even Cu_1 and 1st A. Male hypopygium with the outer dististyle more or less compressed, notably so in *platystyla,* the apex bidentate; inner dististyle deeply bilobed. Ovipositor with the valves elongate, nearly straight.

Type of the subgenus, *Limnophila pilifer* Alexander. (Eastern Palæarctic Region.)

Other included species are *L. breviramus* Alexander, *L. flavella* Alexander and its variety *saitamæ* Alexander, *L. platystyla* sp.

nov. and *L. macrotrichiata* Alexander of Japan and Formosa, and *L. punctum* (Meigen) of Europe.

I had formerly considered the members of this group as being referable to the subgenus *Lasiomastix* Osten Sacken, but the male hypopygium of the latter is distinct, the basistyles being elongate and the inner dististyle simple.

LIMNOPHILA (TRICHOLIMNOPHILA) PLATYSTYLA sp. nov.

General coloration brown, usually dark brown; antennæ (male) relatively elongate, the flagellar segments with their lower faces bulging; wings grayish, with abundant macrotrichiæ in the outer cells; male hypopygium with the outer dististyle very broad, greatly compressed.

Male.—Length, about 5.5 millimeters; wing, 6 to 6.2; antenna, about 2.3.

Female.—Length, about 6 millimeters; wing, 6 to 6.1.

Rostrum dark brown; palpi black. Antennæ with the basal segment of the scape reddish brown; flagellum dark brown; antennæ (male) relatively elongate, as shown by the measurements; flagellar segments with their lower faces protuberant, the surface with a delicate erect white pubescence and a few verticils. Head dark brown, the anterior vertex paler.

Mesonotal præscutum varying from yellowish brown to dark brown, darkest medially, the surface sparsely dusted; pseudosutural foveæ black; scutal lobes likewise varying from yellowish brown to dark brown, the median area a little paler than the lobes; scutellum and postnotum pale brown, the surface sparsely pruinose. Pleura dark brown, the dorsal region of the sternopleurite paler to produce a broad vague paler stripe; dorsopleural region dusky. Halteres pale brown, the base of the stem restrictedly obscure yellow, the knobs infuscated. Legs with the coxæ and trochanters obscure yellow; femora obscure yellow, the tips scarcely darkened; tibiæ brownish yellow, the tips weakly infuscated; tarsi passing into dark brown. Wings with a strong grayish suffusion, the small stigma a little darker; veins dark brown. Macrotrichiæ of cells abundant, including all distal cells from R_2 to Cu, inclusive, in some specimens even including the outer end of cell 1st A. Venation: R_2 about one-third R_{1+2} and only a little shorter than R_{2+3+4}; cell M_1 a little longer than its petiole; cell 1st M_2 small; m-cu variable in position, ranging from before to beyond midlength of the cell.

Abdomen, including the hypopygium, brownish black, the basal segments vaguely brightened except laterally. Male hypopygium (Plate 2, fig. 21) with the outer apical angle of the basistyle somewhat conically produced. Outer dististyle very broad, greatly compressed, the apex narrowly blackened, bifid, the outer spine more slender and less curved than the inner. Inner dististyle with the outer branch expanded at apex into an obtuse head which is densely set with conspicuous setiferous tubercles; inner branch small, likewise conspicuously setiferous.

Habitat.—Formosa.

Holotype, male, Mount Rantaizan, altitude 7,000 feet, June 2, 1927 (*S. Issiki*). Allotopotype, female. Paratopotypes, one male, two females.

ATARBA LEPTOXANTHA sp. nov.

Allied to *A. pallidicornis* Edwards in the general pale yellow coloration, with the femoral tips narrowly darkened, but the mesonotum is uniformly reddish yellow.

Male.—Length, 5 to 5.2 millimeters; wing, 6 to 6.3.

Female.—Length, 5.5 to 5.8 millimeters; wing, 6.8.

Rostrum and basal segments of the palpus yellow, the terminal palpal segments brownish black. Antennæ uniformly pale yellow. Head yellow.

Mesonotum reddish yellow, the sides of the præscutum paler, more yellowish testaceous. Pleura reddish yellow. Halteres pale yellow, the knobs brighter. Legs with the coxæ concolorous with pleura; trochanters yellow; femora light yellow, the tips very narrowly but conspicuously dark brown; tibiæ yellow, the tips even more narrowly and conspicuously infuscated; tarsi yellow, the terminal segments a little darker. Wings with a strong pale yellow suffusion, sometimes with faint brown streaks in the bases of cells C and Sc; veins brighter yellow. Venation as in *pallidicornis* but R_{3+4} shorter and straighter.

Abdomen brownish yellow, the terminal segments a little darker. In the female the tergites are pale brown, the sternites paler, weakly bicolorous, the apices of the segments being broadly but slightly infuscated.

Habitat.—Formosa.

Holotype, male, Tattaka, altitude about 7,400 feet, August 17, 1921 (*T. Esaki*). Allotype, female, Arisan, altitude 7,362

feet, August 24, 1921. Paratopotypes, three males, August 18, 1921.

CERATOCHEILUS FORMOSENSIS sp. nov.

General coloration dark brown; antennæ black; wings pale grayish; R_{2-3+4} long, gently sinuous; veins Cu and 1st A approximated basally for a short distance only; male hypopygium with the outer dististyle entirely blackened; gonapophyses elongate-filiform.

Male.—Length (excluding rostrum), about 4.3 millimeters; wing, 5.2; rostrum, about 4.

Rostrum elongate, almost as long as the remainder of the body, black throughout. Antennæ black. Head in front gray, the posterior vertex darker; anterior vertex of moderate width, at narrowest point approximately one-sixth the head; eyes more narrowly separated beneath, the exact distance uncertain because of a slight crushing of the head.

Mesonotal præscutum with three nearly confluent dark brown stripes; scutal lobes similarly colored; median region of scutum, the scutellum and postnotum a little paler, sparsely pruinose. Pleura dark brown, the dorsopleural membrane paler. Halteres pale, the knobs dusky. Legs with the coxæ and trochanters testaceous; remainder of legs passing into dark brown, the femoral bases narrowly paler. Wings with a pale grayish tinge, C and Sc a little brighter; veins pale brown. Macrotrichiæ on veins relatively long and abundant, distributed as follows: Rs, 1; basal section of R_5 about 7; distal section of the same very numerous and crowded, occurring the whole length of the vein; on distal sections of M_{1+2} and M_3; none on R_{2-3-4}. Venation (Plate 1, fig. 9): Sc_1 ending opposite the origin of Rs, the latter shorter than the basal section of R_5; R_{2-3-4} long, gently sinuous; vein R_5 powerful, diverging widely from the other branch of Rs; cell 1st M_2 closed; m-cu just before the fork of M; approximation of veins Cu and 1st A slight.

Abdomen brown. Male hypopygium (Plate 2, fig. 25) with the ninth tergite bearing two low lateral lobes that are sparsely setiferous. Basistyle relatively short and stout; interbasal process pale, compressed, the flattened head obtuse. Dististyle entirely blackened, the outer lateral angle produced into a slender rod; surface of the style with a few microscopic setulæ,

smaller along the margin. Gonapophyses appearing as two elongate, filiform rods.

Habitat.—Formosa.

Holotype, male, Mount Rantaizan, altitude 6,000 feet, June 3, 1927 (*S. Issiki*).

LIPSOTHRIX TAIWANICA sp. nov.

General coloration pale brownish yellow, the præscutum with four darker brown stripes; legs pale, the tarsi whitened; wings strongly tinged with brown; basal section of R_5 strongly arcuated.

Male.—Length, 5.5 to 6 millimeters; wing, 6 to 6.8.

Described from alcoholic specimens.

Rostrum very small, pale; palpi pale brown. Antennæ pale, the outer segments darker; flagellar segments oval. Head pale brownish yellow.

Mesonotum obscure yellow, the præscutum with four brown stripes, the intermediate stripes separated only by a capillary pale vitta; scutal lobes conspicuously variegated with dark brown; scutellum pale at base, the apex dusky; postnotum pale. Pleura pale, the ventral pleurites a little darker. Halteres pale. Legs relatively long and slender; coxæ and trochanters pale; femora and tibiæ pale brown, the genua vaguely paler; tarsi paling to whitish, the claws black. Wings with a strong brown tinge, the center of the disk a little paler; veins darker than the ground color; macrotrichiæ dark brown, of moderate length only. Venation (Plate 1, fig. 10): Sc_1 ending about opposite one-third the length of R_{2+3+4}, Sc_2 near its tip; Rs relatively long; R_{2+3+4} longer than the basal section of R_5; R_2 a little longer than R_{1+2}; R_{2+3} shorter than R_3; m shorter than the outer deflection of M_3, in cases much shorter; m-cu at or close to the fork of M.

Abdomen pale brown, the basistyles more yellowish. Male hypopygium (Plate 2, fig. 26) with the basistyles relatively short and stout, the interbasal process appearing as a relatively slender pale rod. Outer dististyle heavily blackened, except at base, dilated outwardly, terminating in an acute spine; a second, slightly more curved spine on the mesal edge some distance from the tip, the space between these two spines appearing as a flattened blade. Inner dististyle pale with conspicuous setæ.

Habitat.—Formosa.

Holotype, male, west side of Mount Daibu, altitude 3,000 to 5,000 feet, mid-March, 1927 (*S. Issiki*). Paratopotypes, four males.

The discovery of a species of *Lipsothrix* in the Oriental Region is of considerable interest. *Limnophila sylvia* Alexander described from northeastern North America, should be transferred to *Lipsothrix.*

Genus RIEDELOMYIA novum

Rostrum short; palpi small, the terminal segment shorter than the penultimate. Antennæ (Plate 2, fig. 23) sixteen-segmented, the basal four to six segments of the flagellum closely united to form an elongate-conical fusion segment; first flagellar segment narrowed at base; segments 2 and 3 much wider than long; segment 4 a little longer than wide; remaining flagellar segments becoming elongate-cylindrical, the last segment longest; verticils of fusion segment relatively short and unilaterally arranged, on the outer segments becoming very long and conspicuous, between two and three times the segments; on the basal nine flagellar segments there are no outstanding verticils on the inner face of the segments; on the tenth and succeeding segments such a verticil is present, placed more distad than the verticils of the lateral face; terminal segment elongate, with four long terminal verticils. Vertex relatively wide. Pronotum massive. Pseudosutural foveæ large, elongate-oval; no tuberculate pits; meron greatly reduced. No tibial spurs; tarsi shorter than the tibiæ; tarsal claws relatively large, untoothed; arolia present. Wings (Plate 1, fig. 11) with Sc long, Sc_1 ending beyond the fork of Rs, Sc_2 some distance from the tip of Sc_1, being equal to or longer than m-cu alone; Rs long, strongly arcuated at origin, nearly in alignment with R_{2+3+4}; R_2 about two-thirds R_{2+3+4} and about twice R_{1+2} alone; cell R_2 very wide at margin; basal section of R_5 strongly arcuated; cell 1st M_2 closed, long to very long, m-cu close to the fork of M; veins Cu_1 and 2d A bent strongly into the wing margin; arculus pale but preserved. Ovipositor with relatively long valves, the tergal valves only gently upcurved.

Genotype, *Riedelomyia gratiosa* sp. nov. (Oriental Region.)

Other included species are *R. niveiapicalis* (Brunetti) of India and *R. teucholabina* (Alexander) of Fiji. This new group is named in honor of my old friend, Postamtrat M. P. Riedel, distinguished authority on the Tipulidæ.

The exact affinities of the species included in this new genus remain somewhat in doubt. The species hitherto described were placed in different genera of the Limoniini (*Dicranomyia* and *Limonia*) but a resemblance to *Teucholabis* was observed in the

case of both species. From a critical survey of the characters, as listed, it would now appear that the genus *Riedelomyia* should be placed in the Eriopterini in the general vicinity of *Teucholabis* and *Gonomyia*.

The first member of this group to be described was *Dicranomyia niveiapicalis* Brunetti[4] from the North Canara District, Southwest India. The describer did not stress the essential characters of the fly, but in the same paper[5] discussed a second specimen of the genus that was referred to *Teucholabis* with a querry. The latter specimen has been restudied and is made the type of the genus under the name *Riedelomyia gratiosa* sp. nov. In his extremely valuable review of the Oriental Tipulidæ described by Brunetti, Edwards[6] has reëxamined the type of *niveiapicalis*, has added further notes on the structure and coloration, and has indicated the relationship to *Teucholabis*. The probability that a new genus would be necessary to receive this fly was indicated.

The second species was described from Fiji as *Limnobia? teucholabina* Alexander[7] and likewise was indicated as being an aberrant type that would probably require a new group for its reception. The antennæ of the latter species were not well preserved in the unique type specimen. The venation is about as in the genotype, differing as follows: Sc even longer, Sc_1 and R_1 close together at wing margin; cell R_2 not so wide, vein R_3 being strongly upcurved at outer end; cell 1st M_2 very elongate, longer than any of the veins issuing from it.

The construction of the fusion segment of the antennæ appears to vary rather surprisingly in the different species, and perhaps in the sexes of the same. *Riedelomyia niveiapicalis*, according to Edwards's observation on the dried type, has the basal six flagellar segments almost united into a large cone, the remaining segments of the flagellum very slender, with long verticils. *Riedelomyia gratiosa* has about four segments so involved in the fusion segment, while *R. teucholabina* would seem, from a study of the imperfectly preserved dried type, to have not more than three or four segments involved in the fusion.

[4] Rec. Ind. Mus. **15** (1918) 285–286.

[5] T. c. 306.

[6] Rec. Ind. Mus. **26** (1924) 297.

[7] Ann. & Mag. Nat. Hist. IX **8** (1921) 553–554.

RIEDELOMYIA GRATIOSA sp. nov.

? *Teucholabis* sp. BRUNETTI, Rec. Ind. Mus. 15 (1918) 306.

General coloration brown, the præscutum with four narrow dark brown stripes; pleura dark brown, with a narrow pale longitudinal stripe; wings grayish yellow, sparsely spotted with darker.

Female.—Length, about 7.5 millimeters; wing, 6.5.

Rostrum brown; palpi brownish black. Antennæ (Plate 2, fig. 23) as described under the genus; scapal segments brown, the basal five or six segments of the flagellum orange, the remaining segments passing into dusky. Head brown.

Pronotum pale brown above, dark brown laterally. Mesonotal præscutum brownish yellow with four narrow dark brown stripes, the intermediate pair separated from one another by a subequal distance; sublateral stripes very short; lateral margins of the præscutum and scutal lobes narrowly darkened; remainder of mesonotum chiefly dark brown, the surface more or less yellowish gray pollinose; posterior portion of the postnotum pale. Pleura almost covered by two broad dark brown stripes, leaving only the dorsopleural region and a very narrow longitudinal stripe pale, yellowish pollinose; the dorsal brown stripe extends from the cervical sclerites to the pleurotergite, passing dorsad of the halteres; the ventral stripe extends from the fore coxæ to the base of the abdomen; the narrow pale dividing stripe extends from the extreme base of the fore coxa, passing across the dorsal sternopleurite and ventral pteropleurite to the posterior postnotum, including the base of the haltere. Halteres pale, the knobs weakly darkened. Legs with the fore coxæ infumed except at base, the remaining coxæ pale; trochanters yellow; only a single (posterior) leg remains; femora yellow, the tip narrowly but abruptly whitened, preceded by a slightly narrower brown ring; tibiæ yellow, the distal fifth paling into white; basitarsi white, the outer tarsal segments more yellowish. Wings with a grayish yellow suffusion, the base and cells C and Sc brighter; a heavy spotted brown pattern, distributed as follows: At h; arculus; origin of Rs, extending caudad to vein M; Sc_2; stigma; origin of basal section of R_5; remainder of cord and outer end of cell 1st M_2; small brown marginal clouds at ends of all the longitudinal veins except Sc_1. Paler grayish brown clouds as follows: A transverse series before the wing tip, extending from costa across cells R_2, R_4, and R_5; a conspicuous wash beyond midlength of cell M adjoining vein Cu_1;

smaller washes in the anal cells adjoining vein 2d A, including two in cell 2d A and one near the base of cell 1st A; veins yellow, dark brown in the infuscated areas. Venation (Plate 1, fig. 11) as defined under the genus.

Abdomen discolored, brown, the segments appearing darker brown laterally; sternites paler brown, darker laterally, the caudal margins narrowly pale.

Habitat.—India.

Holotype, female, Parambikulam, Cochin State, altitude 1,700 to 3,200 feet, September 16 to 24, 1914 (*F. H. Gravely*). Type in the collection of the Indian Museum.

The present species is allied to *R. niveiapicalis* (Brunetti), differing especially in the details of coloration and structure. The broad dark stripes of the thoracic pleura are very different in their arrangement. The type of *niveiapicalis* has not been studied, but Edwards describes the ventral stripe as extending from the neck to the base of the abdomen. In *gratiosa* this stripe extends from the fore coxa to the base of the abdomen, the dorsal stripe being the one that includes the neck and lateral propleura.

Genus TAIWANINA novum

Rostrum slender, approximately two-thirds as long as the remainder of the head, clothed with a very delicate pubescence and long scattered setæ; palpi greatly reduced or lacking. Antennæ (Plate 2, fig. 24) twelve-segmented, short, the scapal segments enlarged, especially the large, oval second segment; flagellum with only ten evident segments, the basal one a large fusion segment which is only slightly separated from the following segment; nine flagellar segments beyond the fusion segment, these short-cylindrical, becoming longer and more slender outwardly; outer segments very elongate, with conspicuous setæ, the terminal segment with the tip narrowed, provided with four long setæ; vestiture of the flagellar segments including three distinct types of setæ, very elongate verticils, a microscopic pubescence, and small setæ set in conspicuous punctures. Anterior vertex relatively narrow, approximately twice the diameter of the first scapal segment; eyes beneath narrowly contiguous. Pronotum of moderate size, hidden beneath the produced præscutum. Tuberculate pits present, placed close together at the cephalic margin of the præscutum; pseudosutural foveæ relatively large, lying close to the margin of the sclerite. Meron greatly reduced, the middle and posterior coxæ nearly contiguous.

Legs long and slender; no tibial spurs; setæ of legs simple; claws elongate, slender, simple except for an appressed spine on outer face at about three-fourths the length; arolia lacking. Wings (Plate 1, fig. 12) with Sc moderately long, Sc_1 ending shortly beyond midlength of Rs, Sc_2 a short distance from its tip; Rs relatively short, in alignment with the basal section of R_5; R_{2+3+4} at origin subperpendicular to the end of Rs, thence gently sinuous to the margin; R_2 lacking; R_3 and R_4 fused to margin, obliterating cell R_3; r-m much shorter than the basal section of R_5; cell M_1 lacking; cell 1st M_2 closed, its inner end arcuated; m-cu at or beyond midlength of the cell, equal to or longer than the distal section of Cu_1; Cu_2 very conspicuous; anterior arculus lacking. Male hypopygium with the tergite produced medially, the apex obtusely rounded. Basistyles relatively short, the two dististyles nearly terminal in position; outer style a slender, nearly straight chitinized rod terminating in two decurved teeth of which the outer is smaller; inner dististyle longer, the outer half narrowed. Ædeagus and gonapophyses inconspicuous. Anal tube conspicuous.

Genotype, *Taiwanina pandoxa* sp. nov. (Oriental Region.)

Despite the loss of cell R_3 of the wing, the new genus *Taiwanina* appears to be placed correctly in one of the lower subtribes of the Eriopterini, near such groups as the Gonomyaria, Toxorhinaria, and Claduraria, with all of which it shows some features in common. The slightly elongated rostrum, with very reduced palpi, together with the structure of the antennæ, reminds one very strongly of the Toxorhinaria; but the setæ of the legs are simple and it seems probable that the relationship is not especially close. The combination of antennal and hypopygial structure, and the wing venation, separates this beautiful little fly as an isolated type. At first sight one is reminded by the venation and short rostrum of the subtribe Heliaria, but the structure of the antennæ and thorax renders such an assignment less probable.

TAIWANINA PANDOXA sp. nov.

General coloration black; pronotum and a longitudinal stripe on the thoracic pleura yellow; halteres yellow, the knobs dark brown; femora black, the bases yellowish; tibiæ orange, the base and apex white; basitarsi obscure orange, the base infuscated, remainder of tarsi white; wings strongly infumed, variegated with yellow, the costa broadly so; intermediate abdominal sternites with a whitish spot on either side at base.

Male.—Length, about 5 to 5.5 millimeters; wing, 5 to 7.2.

Rostrum and remainder of head black. Antennæ brownish black throughout.

Cervical sclerites black, brighter above. Pronotum light yellow. Mesonotal præscutum brown, darker behind, paling into yellowish brown in front, without evident pattern; tuberculate pits and pseudosutural foveæ nearly concolorous; remainder of mesonotum dark brown. Pleura brownish black with a conspicuous pale longitudinal stripe extending from the propleura, narrowed behind, ending beneath the wing root, posteriorly with the surface whitish pruinose. Halteres of moderate length, yellow, the knobs dark brown. Legs with the fore coxæ pale yellowish brown, darker apically, the remaining coxæ and all trochanters black; femora black, the bases broadly and conspicuously yellow, the middle femora almost entirely blackened; tibiæ bright orange, the base narrowly pure white, the apex more broadly of this color, the latter preceded by a more or less distinct darkened ring; basitarsi obscure orange, the extreme base infuscated, the apex and remainder of the tarsi pure white, the terminal segment a trifle more yellowish. Wings strongly infumed, the prearcular and costal regions broadly and conspicuously bright yellow, more rarely a trifle obscured, sending large caudal extensions caudad over the arculus, in cell R before Rs and in cell R_2 beyond Rs; conspicuous yellow marginal spots in outer ends of cells R_2 and R_4; small paler spots in outer ends of cells R_5, 2d M_2, M_3, and M_4; large geminate yellow spots at margin on either side of both anal veins; vague pale centers in the cells adjoining the cord; posterior arculus dark; veins pale brown, C, Sc, and R clear light yellow except where traversed by dark areas. Venation (Plate 1, fig. 12) as discussed under the genus; Rs relatively short, strongly arcuated to weakly angulated at origin; basal section of R_5 variable in length; cell R_4 strongly widened at outer end; anal veins bent abruptly into the margin.

Abdomen black; sternites 3 to 7 laterally at base with a conspicuous oval whitish spot; hypopygium dark, the tergal region paler. Male hypopygium as discussed under the genus.

Habitat.—Formosa.

Holotype, male, Mount Rantaizan, altitude 6,000 feet, June 7, 1927 (*S. Issiki*). Paratopotypes, two males, June 3 to 7, 1927; paratype, alcoholic male, Rengechi, altitude 1,500 to 2,000 feet, end of March, 1927 (*S. Issiki*).

Taiwanina pandoxa is a striking fly similar to no species so far described.

MOLOPHILUS PALLIDIBASIS sp. nov.

Belongs to the *gracilis* group; allied to *M. costalis* Edwards; antennæ whitish; mesonotum pale brown; wings with a grayish yellow tinge, the costal region brighter yellow; male hypopygium with the dorsal lobe of the basistyle a cylindrical fleshy lobe that is setiferous to the blunt apex.

Male.—Length, about 3.5 millimeters; wing, 4.3.

Described from an alcoholic specimen.

Rostrum and palpi brown. Antennæ with the first scapal segment dark, the remainder of the organ whitish. Head ocherous brown, the vertex a little darker.

Pronotum whitish above, darker laterally. Mesonotal præscutum pale brown, the præscutum with scarcely differentiated paler stripes. Pleura brown, the dorsopleural region whitened. Halteres dusky, the knobs a little more whitish. Legs with the coxæ and trochanters obscure yellow; remainder of legs obscure yellow, the tarsi passing into darker. Wings with a grayish yellow suffusion, the costal region brighter yellow; veins brownish yellow, those in the costal region brighter. Venation: R_2 lying proximad of the basal section of R_5; petiole of cell M_3 more than twice m-cu; vein 2d A ending about opposite m-cu.

Abdominal tergites brown, the sternites paler. Male hypopygium (Plate 2, fig. 27) with the dorsal lobe of the basistyle relatively long and slender, cylindrical setiferous to the tip; mesal lobe shorter and broader; a blunt setiferous tubercle near base of the style. Outer dististyle relatively slender, the base expanded, the remainder of the style heavily blackened, the tip narrowed into an acute curved spine; surface of the style with microscopic appressed spinules. Inner dististyle subequal in length to the outer, sinuous, the apex a little widened, obtuse, the inner margin produced into a small spinous point; inner margin of the stem with a few microscopic spinules.

Habitat.—Formosa.

Holotype, male, west side of Mount Daibu, altitude 3,000 to 5,000 feet, mid-March, 1927 (*S. Issiki*).

MOLOPHILUS ALBOCOSTALIS sp. nov.

Belongs to the *gracilis* group; allied to *M. costalis* Edwards; antennæ whitish; mesonotum dark brown, the lateral margins conspicuously yellowish white; wings tinged with brown, the costal margin whitish; a small dark brown spot on the anterior

arculus; male hypopygium with the dorsal lobe of the basistyle a flattened glabrous blade, the tip obtusely rounded.

Male.—Length, about 2.6 to 3 millimeters; wing, 3.3 to 4.2.

Rostrum and palpi dark brown. Antennæ with the basal five or six segments whitish, the outer segments more infuscated. Head yellow, the center of the vertex with a large oval dark brownish gray spot.

Pronotum yellowish white, darker laterally; anterior lateral pretergites yellowish white. Mesonotal præscutum brownish gray, the lateral margins yellowish white; remainder of mesonotum dark brown. Pleura dark brown. Halteres dusky, the base of the stem restrictedly paler. Legs with the coxæ dusky, the middle and hind coxæ a trifle more yellowish; trochanters yellowish testaceous; remainder of legs dark brown, the tarsal segments darker. Wings with a brownish tinge, the costal margin whitish; a small dark brown spot on the anterior arculus; veins pale brown, yellowish in the costal region; macrotrichiæ dark brown. Venation: R_2 lying proximad of the basal section of R_5; petiole of cell M_1 more than twice m-cu; vein 2d A relatively short, ending some distance before m-cu.

Abdomen dark brown, the hypopygium brighter. Male hypopygium (Plate 2, fig. 28) with the basistyle relatively long and slender, the dorsal lobe a flattened glabrous blade, the apex broadly rounded; mesal lobe much shorter, obtuse, provided with a few conspicuous setæ; mesal tubercle of the basistyle lying on distal half of the style. Outer dististyle a slender blackened rod, narrowed gradually to the acute curved apex, the surface with abundant microscopic appressed spinules. Inner dististyle longer and broader, near midlength markedly constricted, the apical half narrowed to the acute tip, this expanded headlike portion with abundant microscopic spinules.

Habitat.—Formosa.

Holotype, male, Mount Rantaizan, altitude 7,000 feet, June 2, 1927 (*S. Issiki*). Paratopotypes, several males.

Molophilus costalis Edwards (Plate 2, fig. 29) and *M. arisanus* Alexander (Plate 2, fig. 30) are readily distinguished from the two allied species described at this time by the elongate spinous dorsal lobe of the basistyle of the male hypopygium. The structure of the styli of these four Formosan species is shown in Plate 2, figs. 27 to 30.

ILLUSTRATIONS

[Legend: *b*, basistyle; *i*, interbase; *o*, outer dististyle; R, radial vein and its branches; Rs, radial sector; *t*, tergite. Venational terminology used, Comstock-Needham-Tillyard, as modified by Alexander. Hypopygial terminology used, Crampton.]

PLATE 1

FIG. 1. *Nesopeza circe* sp. nov., wing.
1*a*. *Nesopeza circe* sp. nov., detail of radial field of wing.
2. *Limonia fraudulenta* sp. nov., wing.
3. *Limonia ebriola* sp. nov., wing.
4. *Eurhamphidia inelegans* sp. nov., wing.
5. *Protohelius issikii* gen. et sp. nov., wing.
5*a*. *Protohelius issikii* gen. et sp. nov., detail of radial field of wing.
6. *Tricyphona kirishimensis* sp. nov., wing.
7. *Tricyphona formosana* Alexander, wing.
8. *Pseudolimnophila descripta* sp. nov., wing.
9. *Ceratocheilus formosensis* sp. nov., wing.
10. *Lipsothrix taiwanica* sp. nov., wing.
11. *Riedelomyia gratiosa* gen. et sp. nov., wing.
12. *Taiwanina pandoxa* gen. et sp. nov., wing.

PLATE 2

FIG. 13. *Tipula tetracantha* sp. nov., details of male hypopygium.
14. *Limonia fraudulenta* sp. nov., male male hypopygium.
15. *Limonia remissa* sp. nov., male hypopygium.
16. *Limonia ebriola* sp. nov., male hypopygium.
17. *Dicranomyia nesomorio* sp. nov., male hypopygium.
18. *Protohelius issikii* gen. et sp. nov., male hypopygium.
19. *Dicranoptycha formosensis* sp. nov., male hypopygium.
20. *Dicranoptycha geniculata* sp. nov., male hypopygium.
21. *Limnophila* (*Tricholimnophila*) *platystyle* sp. nov., male hypopygium.
22. *Liogma pectinicornis* sp. nov., antenna of male.
23. *Riedelomyia gratiosa* gen. et sp. nov., antenna of female.
24. *Taiwanina pandoxa* gen. et sp. nov., antenna of male.
25. *Ceratocheilus formosensis* sp. nov., male hypopygium.
26. *Lipsothrix taiwanica* sp. nov., male hypopygium.
27. *Molophilus pallidibasis* sp. nov., male hypopygium.
28. *Molophilus albocostalis* sp. nov., male hypopygium.
29. *Molophilus costalis* Edwards, male hypopygium.
30. *Molophilus arisanus* Alexander, male hypopygium.

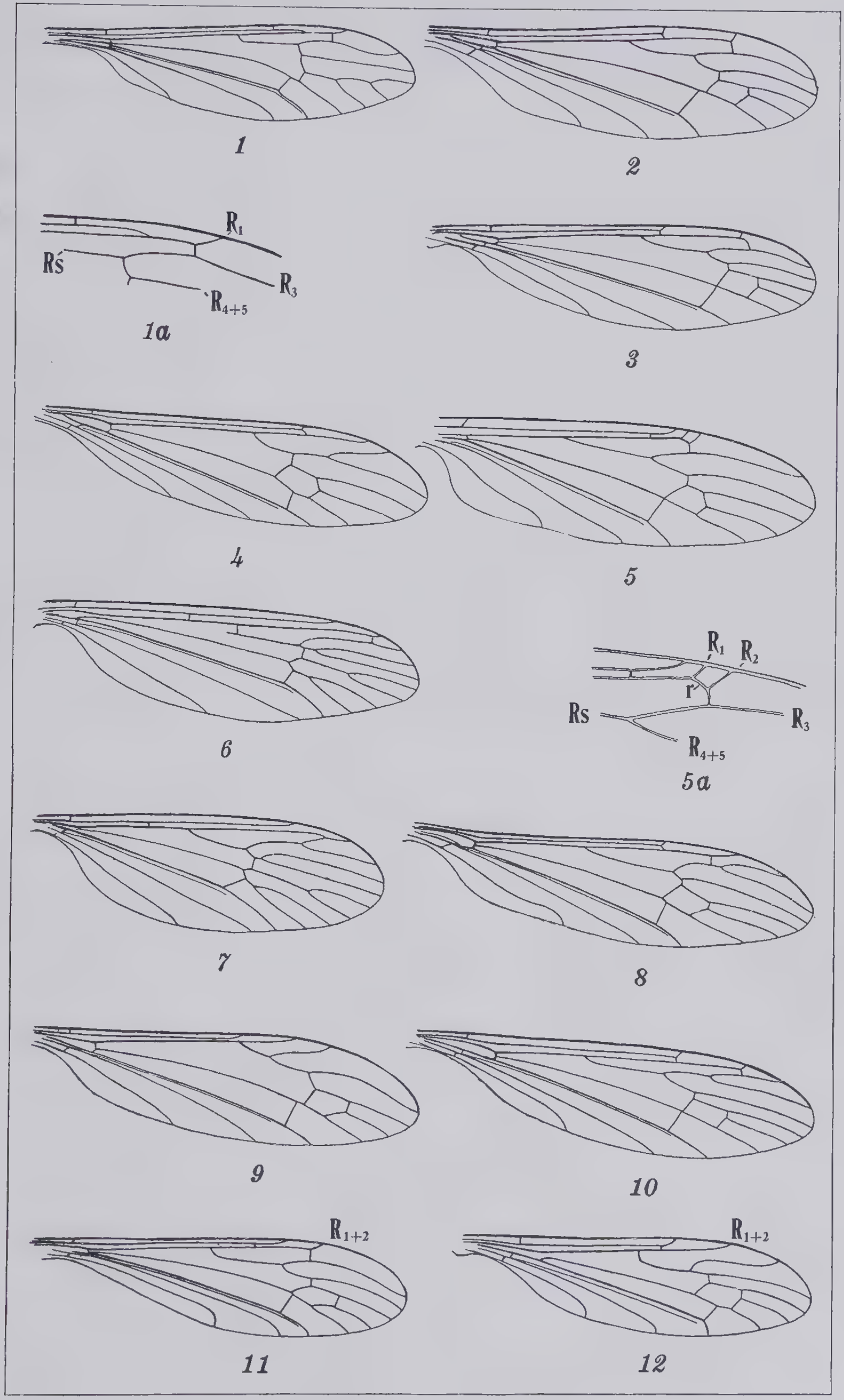

PLATE 1.

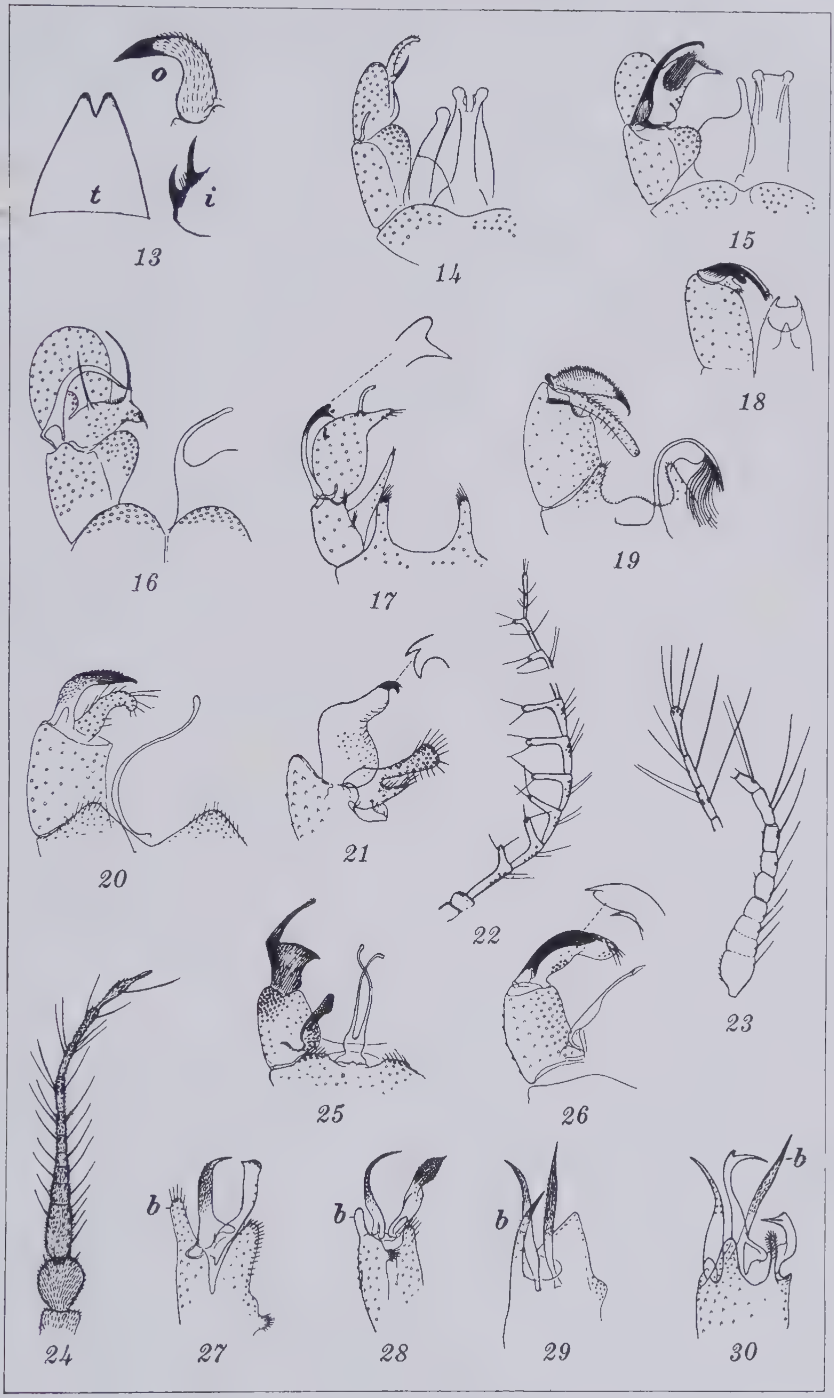

PLATE 2.

ERRATA

Page 55, in the fourth line from the bottom, *for* Chamberlain, *read* Chamberlin,

Page 57, in line 20, *for* giving birth *read* the liberation of

Page 57, in footnote 5, *for* (1912) *read* (1913)

Page 58, in the third paragraph, line 2, cancel the comma.

Page 61, insert a center head INSECTA above the center head ORTHOPTERA

Page 62, in the quotation from Imms, in line 5, *after* soil *insert* very much after the manner of the "casts" of earthworms. In many parts of the tropics there is scarcely a cubic yard of soil

Page 63, footnote 11, in line 2, *for* 234 *read* 243

Page 70, in line 26, *for* by others. *read* by others for *Ochromyia.*

Page 70, in line 29, for *Ochrimyia.* read *Ochromyia.*

Page 72, in the second line from the bottom, for *gibolensis* read *gilolensis*

Page 73, to footnote 29, *add* 210.

Page 75, in the thirteenth line from the bottom, *for* centimeters, *read* centimeters;

Page 75, in the third line from the bottom, cancel both commas.

Page 76, in the sixth line of the quotation, cancel the semicolon.

Page 76, in the sixth line from the bottom, for *chrysogona* read *chrysozona*

Page 80, in line 19, *for* Notoduntidæ *read* Notodontidæ

Page 82, to footnote 37, *add* 325–326.

Page 83, in line 24, for *Chalbyion* read *Chalybion*

Page 83, in the thirteenth line from the bottom, *for* of Bull. *read* of my Bull.

Page 83, in the eleventh line from the bottom, for *interudens* read *intrudens*

Page 86, in the second paragraph, line 2, and in footnote 43, *for* 1927 *read* 1928

Page 87, in the second paragraph, line 5, for *Cephalomomyia.* read *Cephalonomyia.*

Page 93, for line 4, *read* of the nests of certain other ants, like those of *Anoplolepis*—

Page 96, to footnote 57, add the date 1923.

Page 97, line 8, delete the first comma.

Page 97, in line 11, *for* pluræ, *read* plura,

Page 97, in line 22, *for* mesopluræ, *read* mesoplura,

Page 98, in line 5, *for* margination *read* emargination

Page 98, in line 17, *for* margins *read* margin

Page 100, in line 16, *for* reticulate; drawn *read* reticulate, drawn

Page 100, in line 17, *for* place; *read* thorn;

Page 105, in the ninth line from the bottom, cancel "and not very loud."

Page 108, in footnote 65, *for* 187. *read* 185.

Page 108, in footnote 66, *for* 27: 408. *read* 27 (1920) 409.

Page 109, cancel the center heading.

Page 112, in footnote 69, *for* (1922). *read* (1907) 1022.

Page 112, in footnote 70, *for* (September, 1925). *read* (1925) 326.

Page 118, in the description of Plate 7, fig. 1, for *celebensis* read *celebesensis*

INDEX

[New names and new combinations are indicated by **bold-faced type.**]

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